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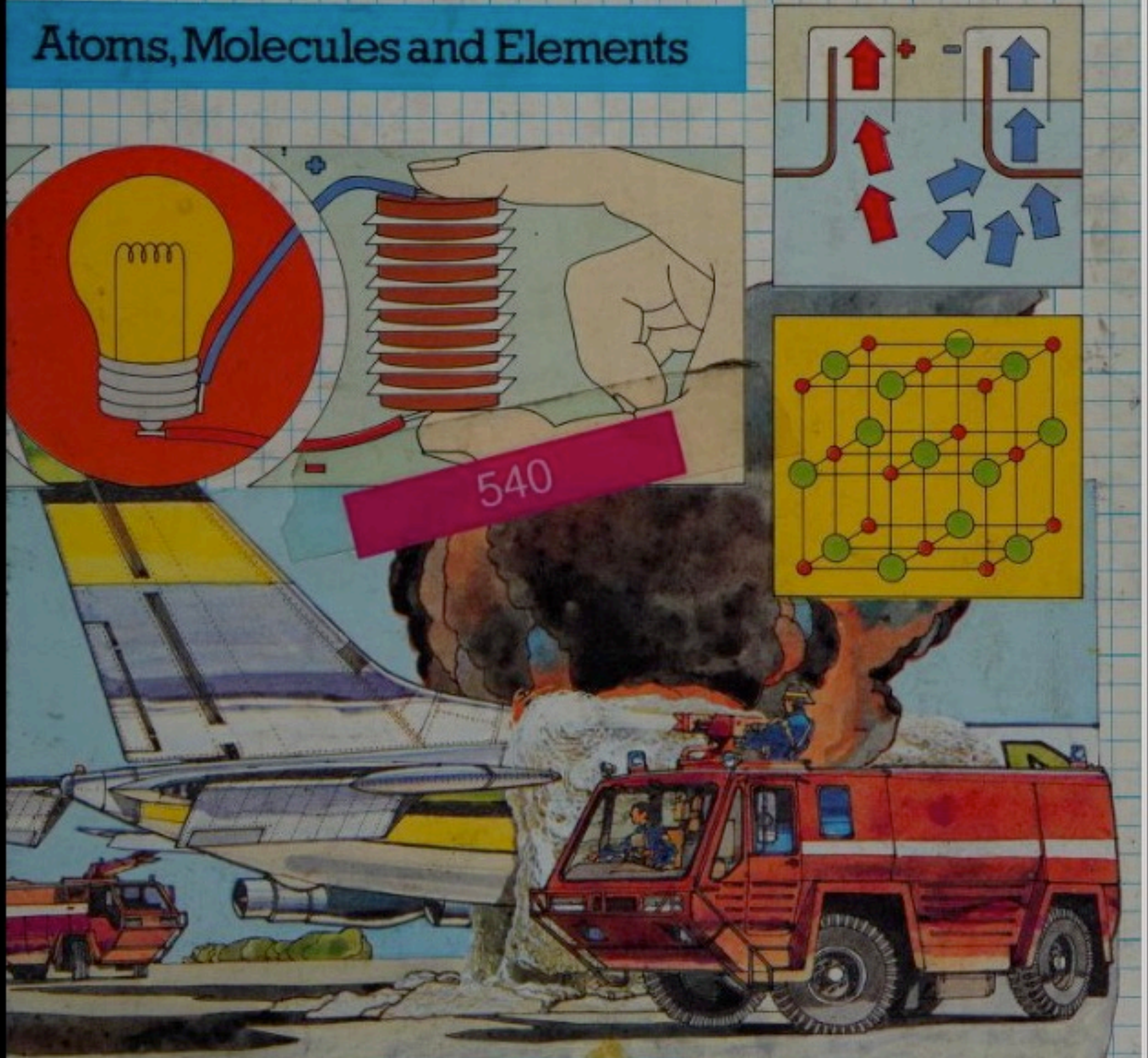
Chemistry

Atoms, Molecules and Elements



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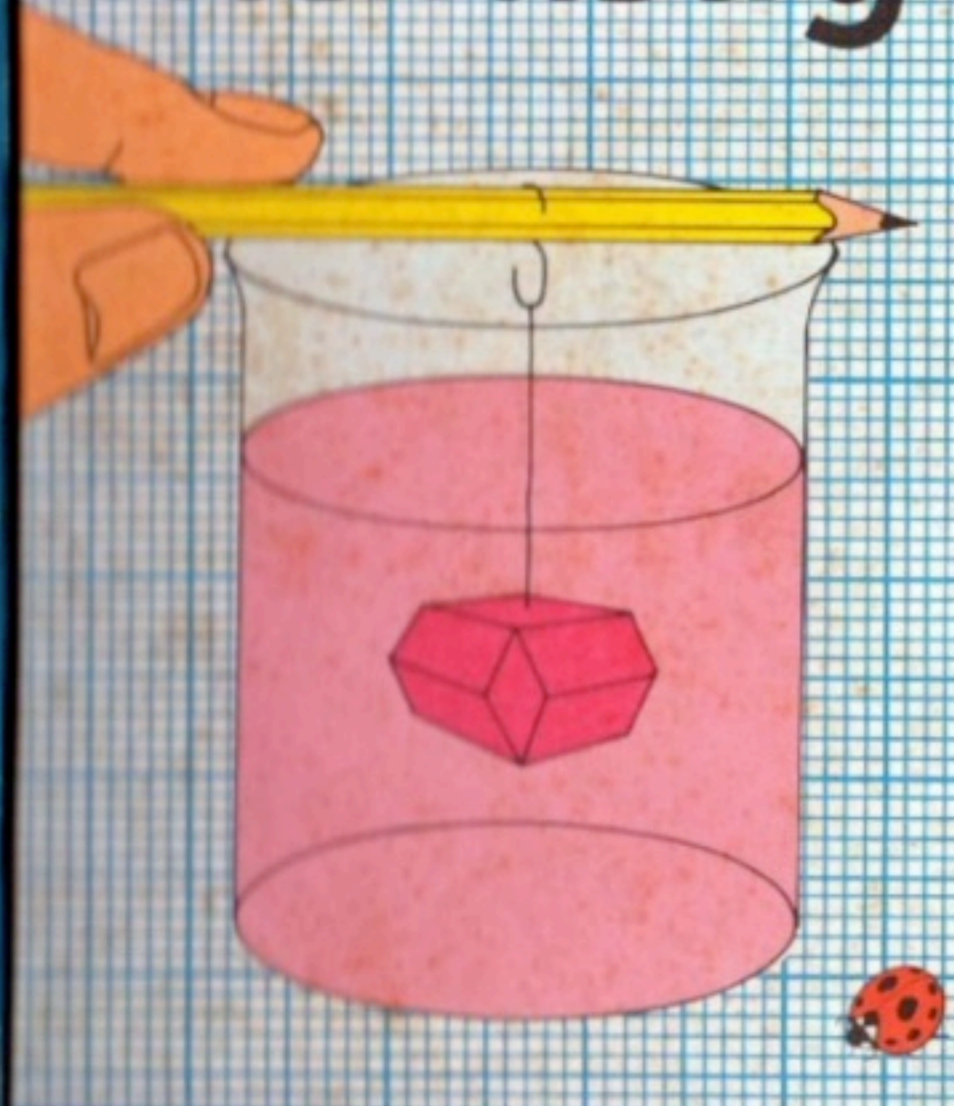

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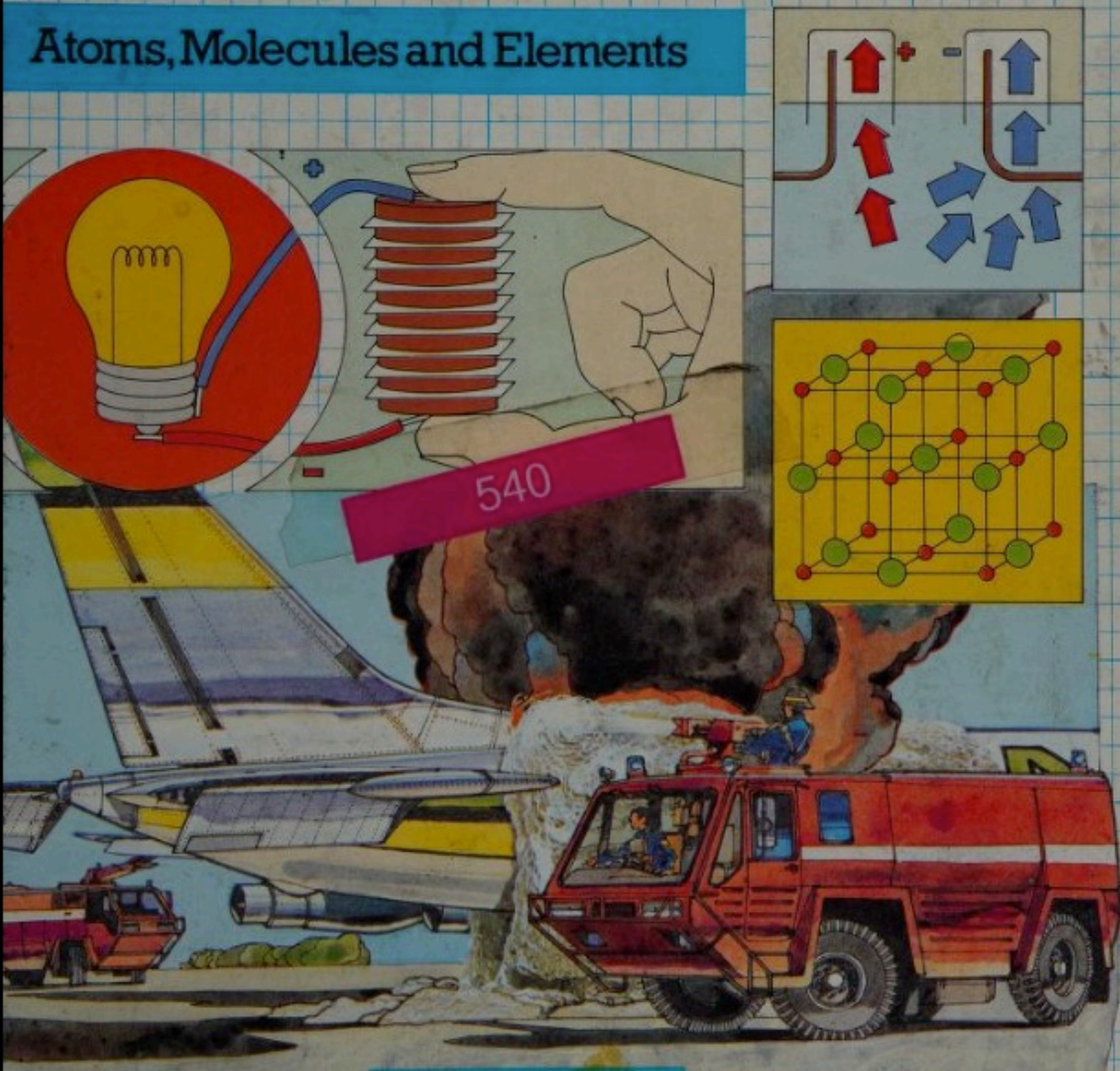

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Franklin Watts Science World

Chemistry

Derek Walters

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Introduction

Chemistry is the science of substances – what they look like, what they do and why. It isn't just a subject for scientists in their laboratories, surrounded by bottles and beakers.

Chemistry can provide the answers to a wide variety of perplexing problems; what happens to paper when it burns; what is water made of; why are lemons sour? One aspect of chemistry deals with finding out what things are made of – this involves breaking down complex chemical substances into their basic constituents. The other side of chemistry is concerned with the invention of new materials, such as plastics, medicines, and even new foodstuffs.

This book introduces the subject through one of the most familiar processes of chemistry – burning – and shows how this is related to rusting, breathing and bleaching. Other types of chemical change – such as decomposition – are illustrated by examples from everyday life, from the homely matter of baking a cake to the splendid spectacle of a firework display. This leads us to the two great classes of chemical substances – acids and bases.

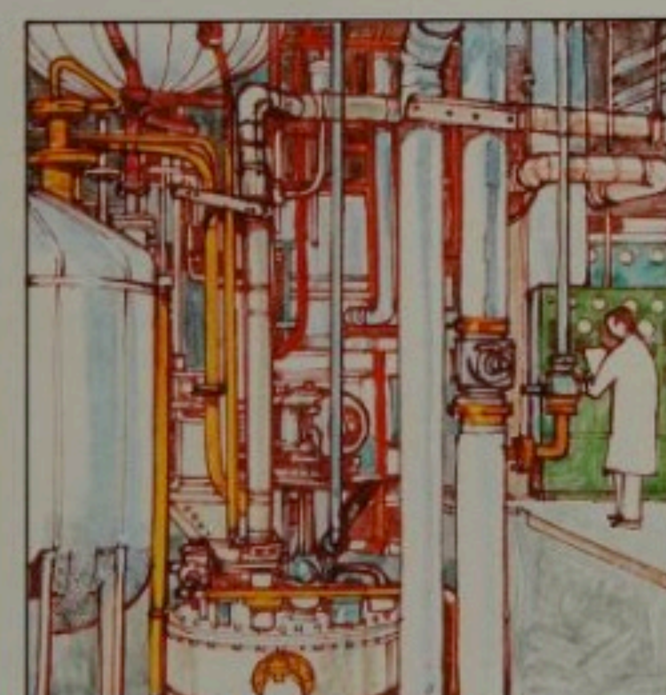
Since one of the products of mixing an acid with a base is water, this is an appropriate place to examine water's curious properties. Splitting water into its component parts by means of electricity introduces the subject of electrochemistry, including the chemical battery and chromium plating. The component parts are elements – the basic substances of which the world around us is composed, and the topic that is treated next. And finally, the elements can be further broken down into atoms – the building blocks of the universe!

Contents

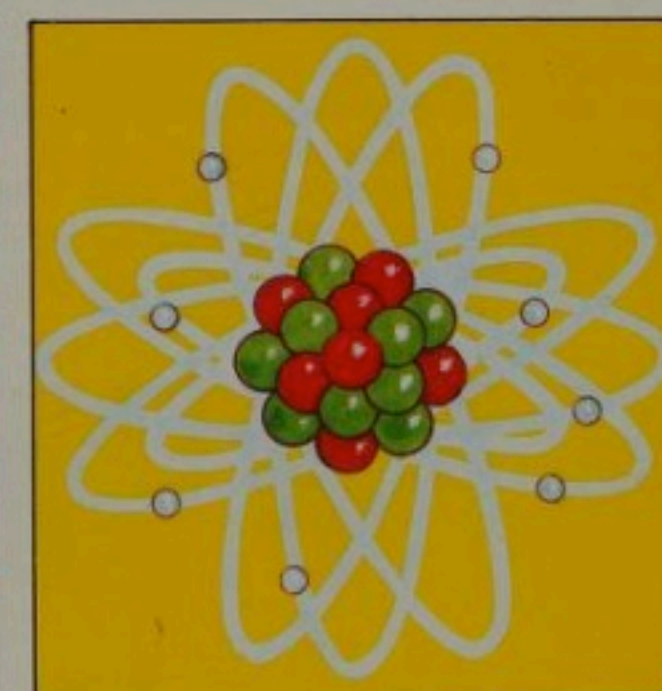
Chemistry affects every aspect of our daily lives. Even something as simple as frying sausages involves chemical processes! And while it is well known that, say, car batteries contain acid, how often do we think of all the acids around us in the kitchen? Yet a few simple tests will prove their presence. Obviously, far more complicated chemical processes are involved in the industrial manufacture of synthetic materials. But however they occur, naturally or otherwise, all chemical substances are made up of the basic elements, whose atomic structure is the key to their behavior.

Burning

Testing for acids



Inside a chemical plant



The structure of an atom

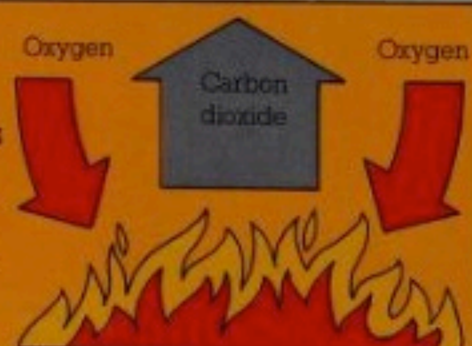
Burning

An airplane has to make an emergency landing. Fuel has started to leak from one of its tanks, and, as the plane touches down, heat from the friction of its tires hitting the ground is enough to set the kerosene fumes on fire. Fortunately, the airport's emergency services have been alerted, and they are on hand immediately to drench the plane with foam. What might have been a major disaster has been brought safely under control. All of which leads us to ask: why is kerosene so dangerous, and how can foam put the fire out?

When fuels such as coal, wood, or oils are burned, most of the fuel seems to disappear into the air, while some heat is given out. Before something will burn, it needs to be "lit" by some other source of heat, such as a match. How much heat is needed to set fire to the fuel depends on the fuel's ignition point. Fuels such as coal, with a high ignition point, usually need another fire – perhaps from burning wood – to make them burn. Once lit, however, the heat from the burning process is enough to keep the fire going. On the other hand, fuels with low ignition points – such as kerosene or butane – have to be stored under special conditions, since the slightest spark is enough to ignite the fuel.

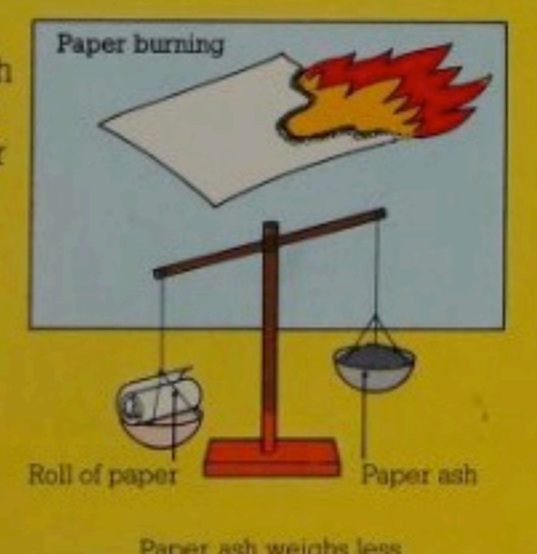
But nothing will burn without air. That is why, in the case of accidental fire, attempts are made to smother the flames with water, sand, blankets or, as with the burning plane, special foam. All these things act as barriers, keeping air away from the flames. Clearly, either the air, or something it contains, is needed for burning to take place. The vital ingredient is oxygen. Oxygen is so important that it is easy to forget that only a fraction of the air around us – just about one fifth – is made up of it. The rest consists mainly of nitrogen, which dilutes the oxygen in the air in much the same way as water is used to dilute concentrated fruit drinks.

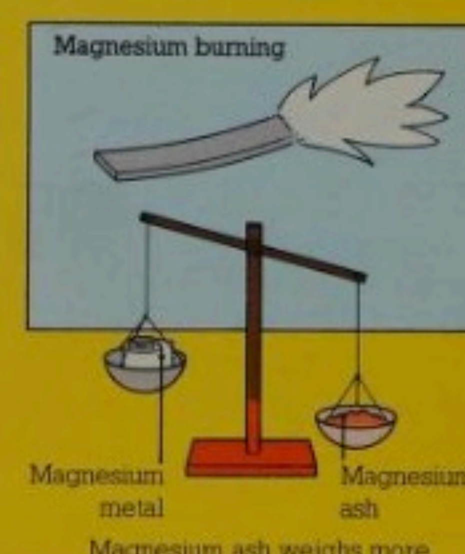
How things burn
Most fuels contain carbon. Charred wood, or charcoal, is almost pure carbon. When this burns in air, it combines with oxygen to make another gas, called carbon dioxide, and gives out heat energy.



△ Firemen race against time to put out the fire before it reaches the aircraft's fuel tanks. The first priority is to keep the air away from the flames. This is done by smothering the flames with a special foam made up of bubbles containing carbon dioxide, in which things cannot burn. Foam has two advantages over water. It can be concentrated on its target more easily, and is easier to transport.

Weighing the ash
When paper is burned, its ash weighs less than the original paper. This is because paper contains a lot of carbon, which is lost to the air as carbon dioxide. But burning magnesium (the metal used in a photo flash), captures oxygen from the air and deposits an ash, magnesium oxide, that will weigh more than the original metal.





Rusting

Cars, bridges, and ships need to be painted regularly to prevent them rusting. Chemically, there is little difference between rusting and burning in air. In both, oxygen is taken from the air to make a new substance. The chemical name for rust is iron oxide. Normally, iron rusts more quickly if it is wet. However, iron can be kept underwater without rusting if the water is first boiled, to drive off its oxygen, and the container sealed with oil to prevent the oxygen from re-entering.

Rust takes its toll

In dry open air

In water and air

Under boiled water and sealed

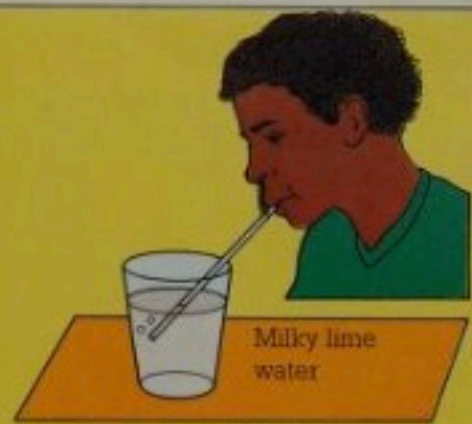
Rusting can be a protection
The oxidation process affecting iron is harmful. As the rust (or iron oxide) falls off it exposes a fresh surface of iron to the air. But the oxygen captured from the air by aluminum helps to form a protective layer that sticks to the surface of the metal and actually prevents corrosion. However, it robs the metal of its shiny appearance.

Cleaning an aluminum pan with wire wool to remove oxide

Divers giving off bubbles of carbon dioxide

Breathing

It can be shown that the oxygen we breathe combines with carbon (from our food) to make carbon dioxide by a natural process of oxidation. "Lime water" is normally clear, but turns cloudy when carbon dioxide is passed through it. The air around us contains only a trace of carbon dioxide, and so does not cause lime water to change color. But the air we breathe out, when bubbled through lime water, will turn it milky, because of the carbon dioxide present.



Breathing into lime water turns it milky

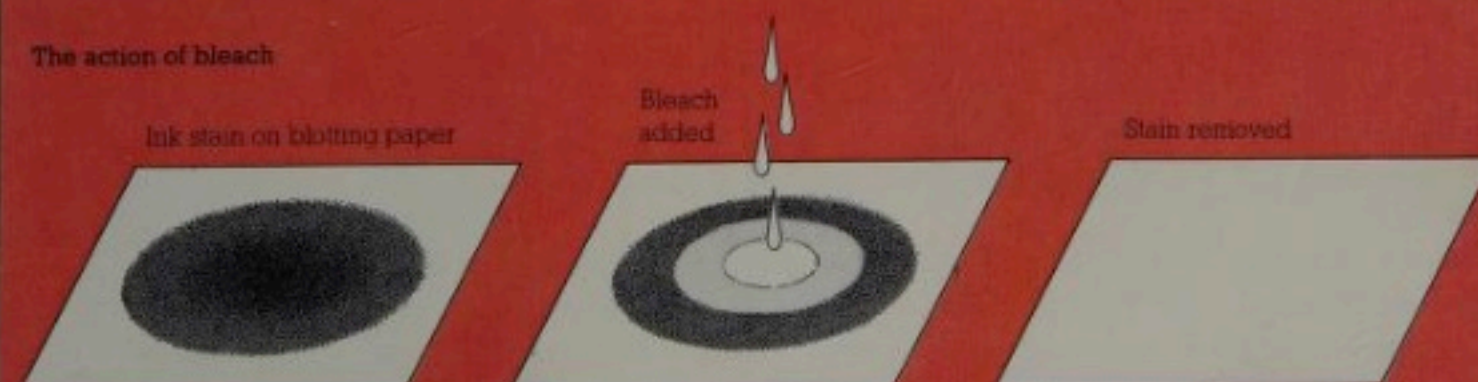
Ordinary air blown through lime water makes little change

Bleaching

Bleach may be used to make grimy or yellowed materials white again, to remove ink stains, or even to "dye" things white. The bleaching process is a form of oxidation, but a very odd one. Oxygen is not taken from the air, but is already contained in the bleach together with another substance, chlorine. Chlorine, however, has a stronger attraction for hydrogen than for oxygen and so, when it comes into contact with, for instance, grease or dyes, that contain hydrogen, it takes away hydrogen and leaves oxygen in its place. The oxides formed as a result are white, which is why the color disappears. Thus bleach does not actually remove grime, dyes or inks from materials. It merely oxidizes them.

Bleaching washing

The action of bleach



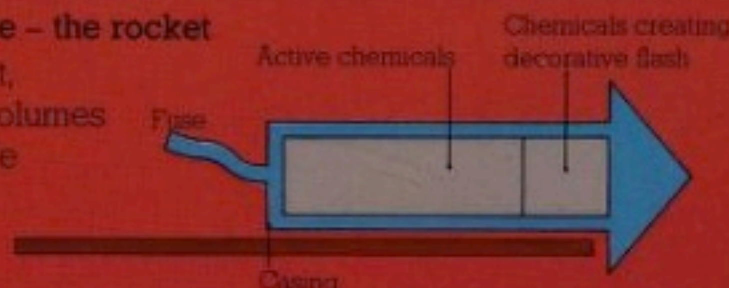
Active Substances

Sometimes, the celebration of a major event is accompanied by a spectacular firework display. In particular, firework displays are a traditional way of commemorating great victories in war; the loud explosions and brilliant flashes that light up the sky recapturing the thrill and excitement of battle while allowing the whole experience to be enjoyed in safety. But how are these gloriously noisy and colorful displays produced?

We saw earlier that in burning, oxygen in the air combines with something else to make a new substance. The opposite happens when a rocket is set off: a compound substance splits up into simpler ones, or decomposes. At least one of these substances is a gas, but produced in such vast quantities, and so suddenly, that it shoots out of the end of the firework, sending it into the air.

An explosive chemical mixture – the rocket

When the fuse to a rocket is lit, chemical reactions produce volumes of hot gas and propel it into the air. Further reactions in the nose produce decorative explosions in the sky.



Other fireworks involve more complicated chemical processes. Roman candles contain a mixture of combined, or compound, substances just waiting for the opportunity to change partners and rearrange themselves into new substances. When this happens, huge amounts of energy are released – the source of the dazzling displays of fire seen as the Roman candle burns. Some of the new substances are shot into the air as fiery sparks; others erupt like lava from miniature volcanoes.

Not all chemical processes are as energetic or spectacular as a firework display. But even striking a match involves a chemical reaction. Heat produced by friction when the match head is rubbed against the side of the box sets off a chemical process similar to that in a firework.

Many chemical processes, instead of giving out heat, need additional heat to make them work. But all chemical processes, great or small, spectacular or not, involve the making or breaking of partnerships between substances.

▷ This firework display illustrates many of the features of chemical change. Solid materials are changed into quite different substances – such as gases – and a lot of energy is given out as heat, light, and sound.

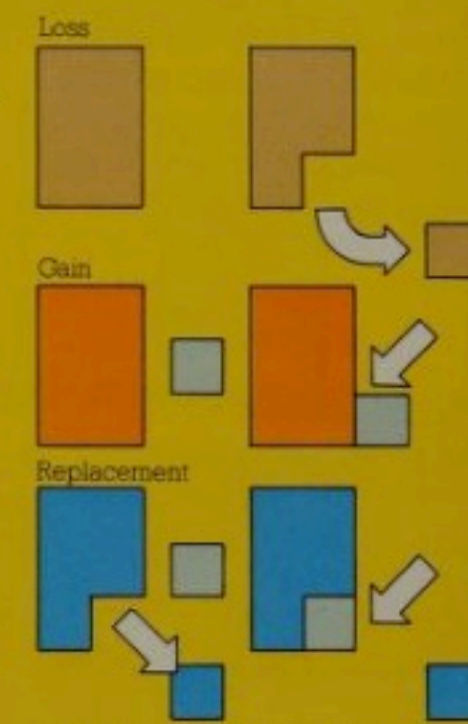
Chemical changes

Loss and Gain

When a chemical compound decomposes, it loses an ingredient and leaves a simpler substance behind. Combination is the opposite of decomposition. A simple substance gains a new ingredient in the course of a chemical reaction.

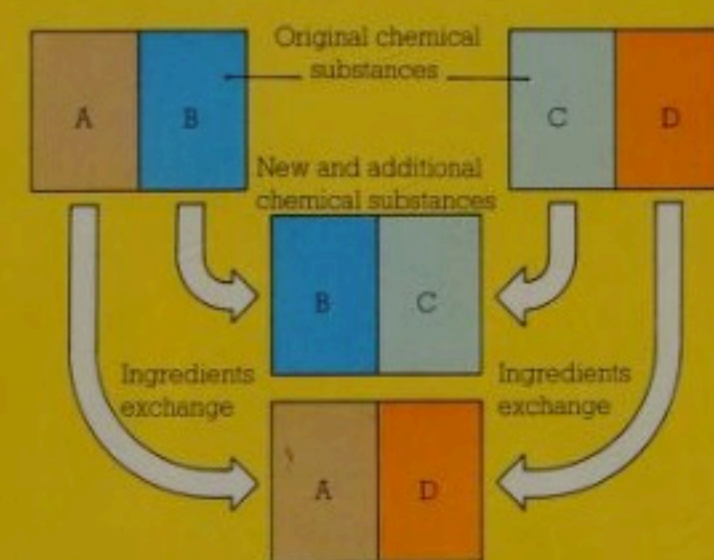
Replacement

Some chemical processes, including bleaching, involve the replacement of one ingredient of a compound by another.



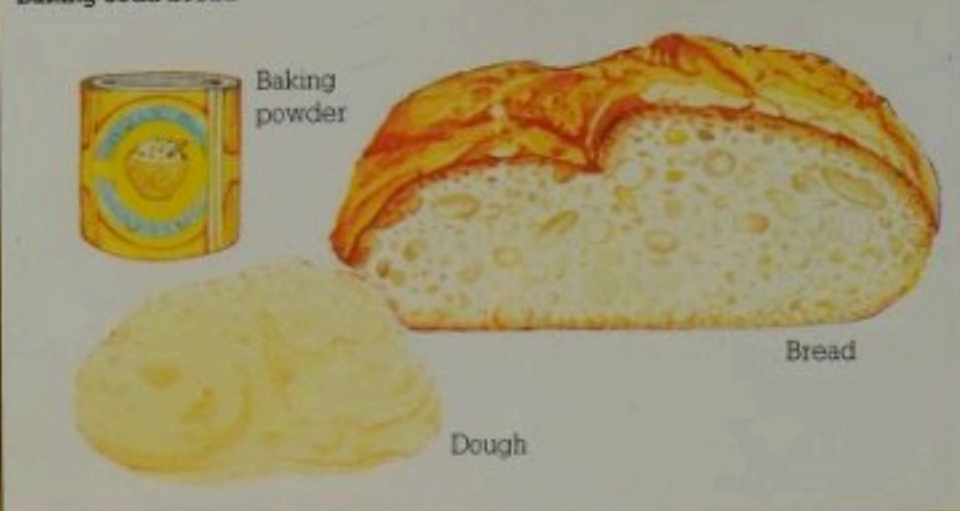
Exchange

In other types of reactions, the ingredients of two substances may be exchanged to form two new substances. Sometimes this exchange is complete, sometimes only partial – the two new substances existing alongside the two original ones, as shown below.



Loss

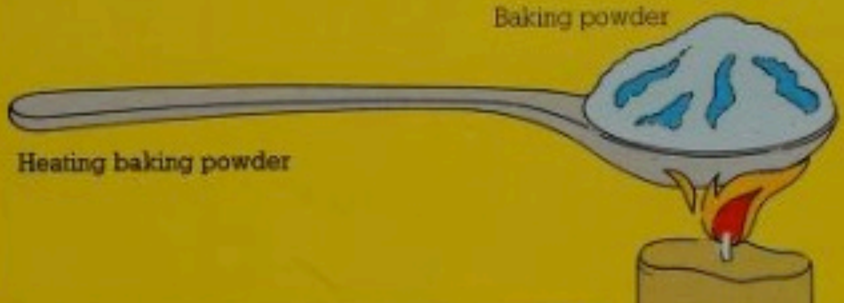
Baking soda bread



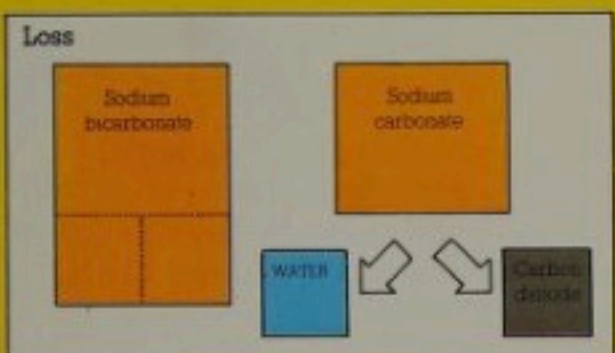
Baking soda
Making soda bread involves a chemical change – the decomposition of baking soda – which converts flat dough into something edible. Baking soda (sodium bicarbonate), when heated, breaks down into sodium carbonate ("washing soda") carbon dioxide and water. Bubbles of carbon dioxide are present throughout the dough, and lift it until the loaf has cooked all the way through.

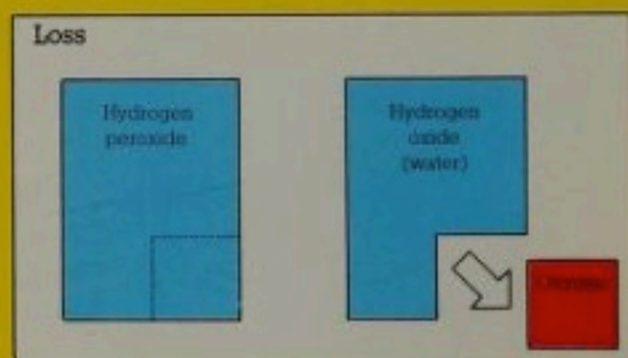
However, if too much baking soda is used, a lot of sodium carbonate will be left behind in the loaf, giving it a soapy taste.

Hydrogen peroxide solution is used as a mild bleach or antiseptic mouthwash. It has the same chemical ingredients as water, but contains extra oxygen. This is easily given up, leaving water behind. If you rinse your mouth with a weak hydrogen peroxide solution, you can feel oxygen bubbles being formed in your mouth.

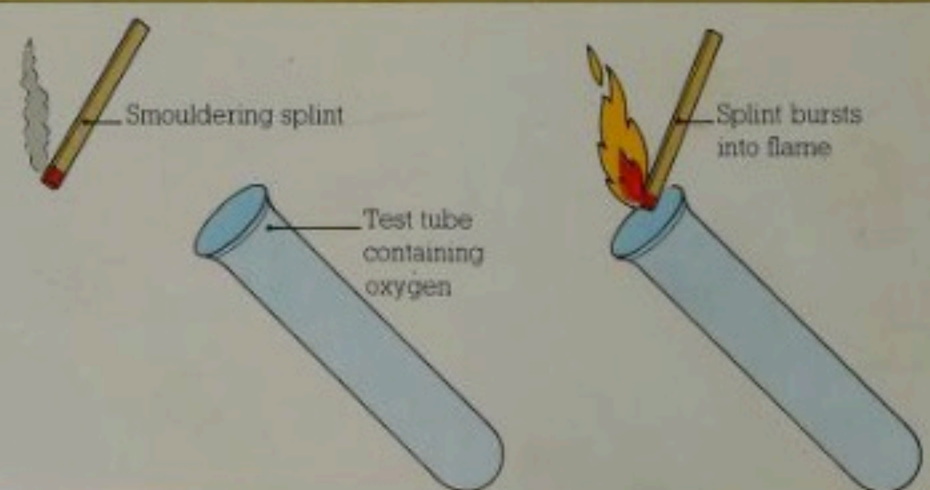


Heating baking powder





Testing for oxygen
Things burn much more readily in pure oxygen than they do in air. If a wooden splint is lit, and then blown out so that it is just glowing red, it will burst into flame again if put into a test tube containing pure oxygen. This is a way of testing for oxygen.

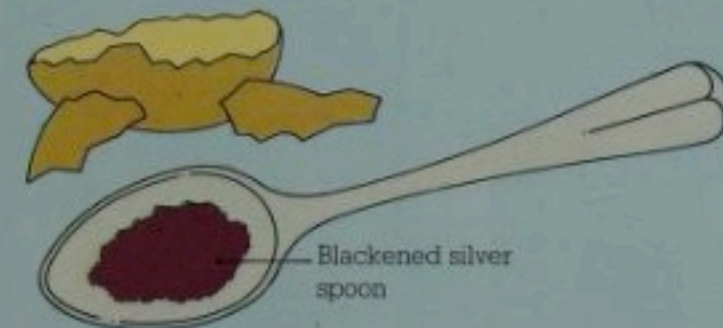


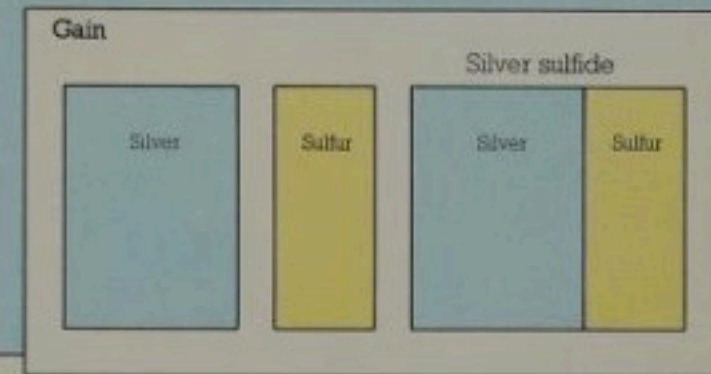
Gain

Silver combines with sulfur to form a black compound, silver sulfide. That is why silver cutlery turns black when it comes into contact with egg, or certain green vegetables, that contain traces of sulfur.

Eating an egg

Chemical names ending in "-ide" usually refer to compounds containing only the substances named. Thus silver sulfide consists of just silver and sulfur. The ending "-ate" as in copper sulfate, means that in addition to copper and sulfur, oxygen has to be one of the ingredients.

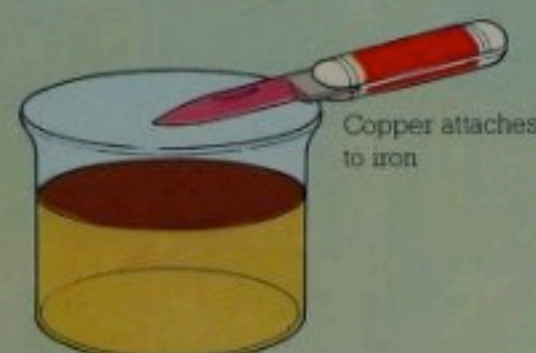


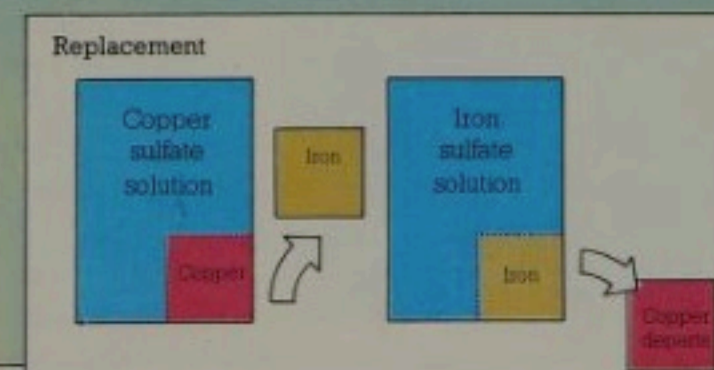


Replacement 1

Copper-plating iron

When an iron penknife blade is dipped into blue copper sulfate solution, it quickly becomes covered with a pink film, which is actually a thin coating of copper. This is an example of replacement. The "sulfate" part of copper sulfate has a very strong attraction for iron, so that, when it comes into contact with the iron blade of the penknife, it pushes the copper out of the way and binds with the iron instead. If the action is continued, all the copper will eventually be deposited on the blade, and a solution of iron sulfate left behind. The brown, rather than pink color that we usually associate with copper, is due to a film of copper oxide which forms when copper is exposed to the atmosphere.

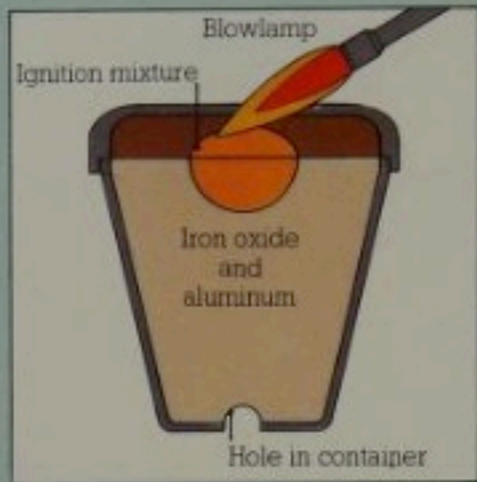




Replacement 2

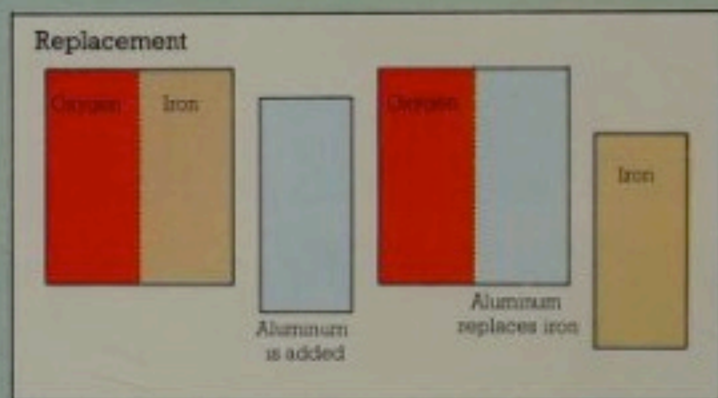
WARNING!
THIS IS A LABORATORY EXPERIMENT

One of the most energetic examples of chemical replacement is so powerful that it produces molten iron. This makes it very useful in remote places for on-the-spot repairs to iron structures. Called the Thermit process, it uses a mixture of powdered aluminum metal and iron oxide.



To start the reaction, a very high temperature is needed, for which an ignition mixture has to be used. As the aluminum replaces the iron in the iron oxide, the molten iron produced by the fierce heat pours through a hole in the special container and runs into the casting mold, or into the joint in need of repair.

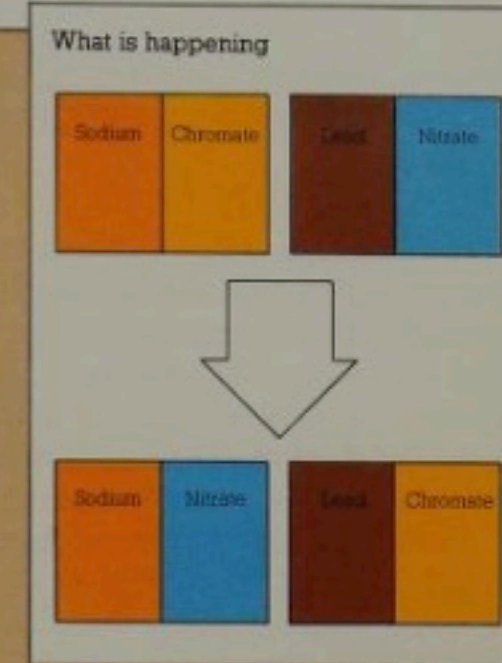
Using the set-up on site



Exchange 2

Chrome yellow is the name given by artists to a bright yellow pigment. Surprisingly, this can be made in the laboratory by pouring one clear liquid into another, when – presto! – the bright yellow pigment suddenly appears! This is another example of the process known as exchange.

Very simply, the two chemical substances involved, sodium chromate and lead nitrate, have exchanged partners to make two new substances, sodium nitrate, which remains in the solution, and lead chromate. This settles at the bottom of the liquid as a very fine yellow powder, chrome yellow.



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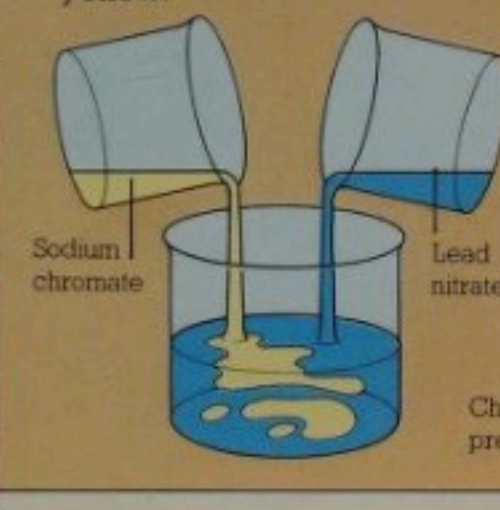
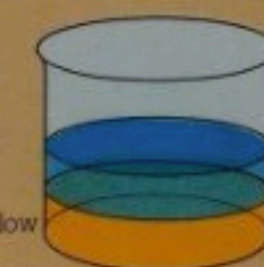
Chrome yellow paint





Chrome yellow precipitate

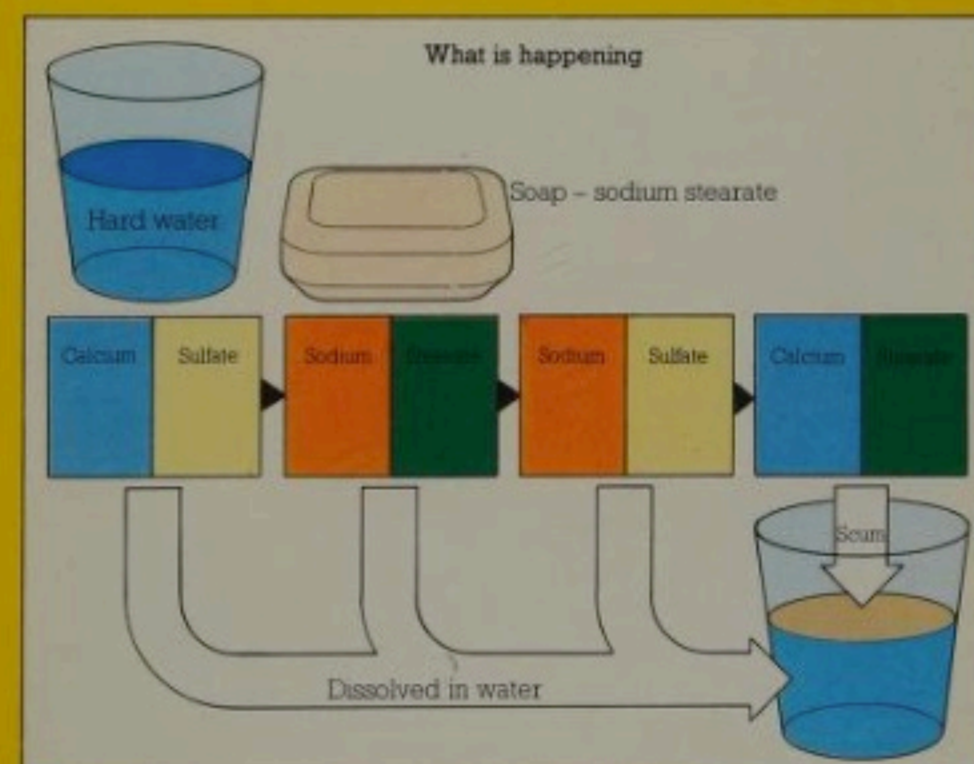
Exchange 1

Calcium sulfate sometimes hardens to form stalactites in damp caves

"Hard" water contains impurities dissolved in it, such as chalk, and when ordinary soap is put into hard water, a precipitate, or scum, forms. This is not only unattractive; it is also wasteful, since it prevents the soap from doing its job until all the chemicals causing the scum have been pushed out of the water. One of the main chemical ingredients of hard water is calcium sulfate. When soap (sodium stearate) is added to hard water, two new substances are formed.

Scummy bath

These are sodium sulfate and calcium stearate. Calcium stearate does not dissolve in water, and instead floats to the surface as the familiar white scum. Sodium and calcium are metals; stearate and sulfate are "radicals." The two metals have exchanged radicals to make two new substances. This type of chemical reaction is known as exchange.



Acids, Bases and Salts

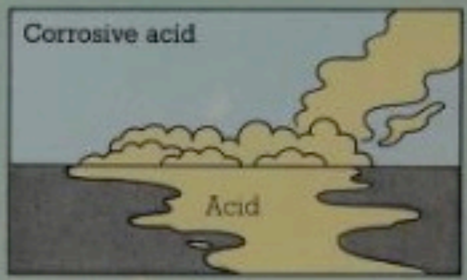
When people see a container labeled ACID, they like to keep well away. After all, it is rather an uncomfortable thought that something that looks as innocent as water can burn its way through leather, iron, steel and other materials that normally offer us protection. Corrosive acids spilled on the roads have been known to eat their way through car tires and the boots of rescue teams.

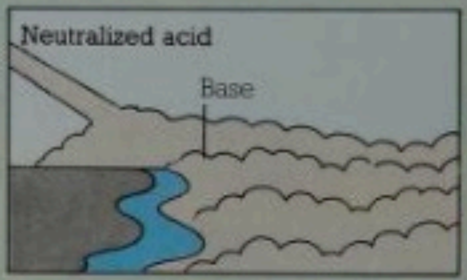
Fortunately, there are other substances – bases – which react with acids and make them safe. Bases are sometimes as powerfully corrosive as acids, but when an acid and a base are mixed together they neutralize each other, producing harmless "salts" and water. Containers carrying dangerous chemicals are marked with a placard identifying the chemical load, and must always carry instructions on the side as to which chemicals should be used as neutralizers in case of an accident.

In view of the reputation acid has, it might come as a surprise to know how many acids there are in the home – even in the kitchen and medicine cupboards. Yogurt, for instance, contains acid, and so does aspirin. Our own bodies, too, produce many complex acids to help build new tissue, carry messages around the body, and digest food.

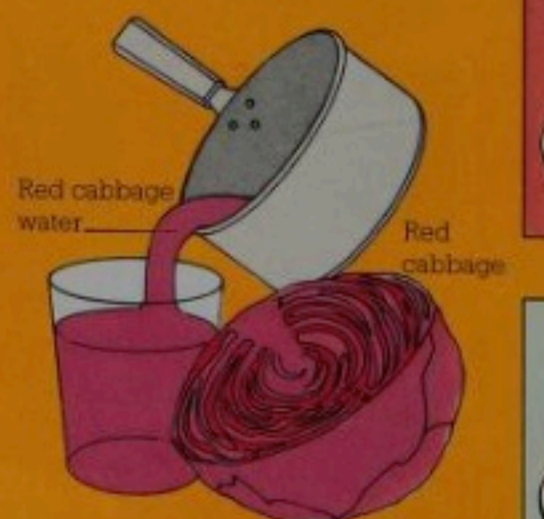
Bases also have their domestic uses. The various kinds of soda found in the home – baking soda, washing soda and caustic soda – are all bases. But the widest used base of all is lime. Besides its agricultural use, lime is a vital ingredient in cement, mortar, plaster and concrete. The lime reacts with carbon dioxide in the air and hardens the mixture as it dries out.

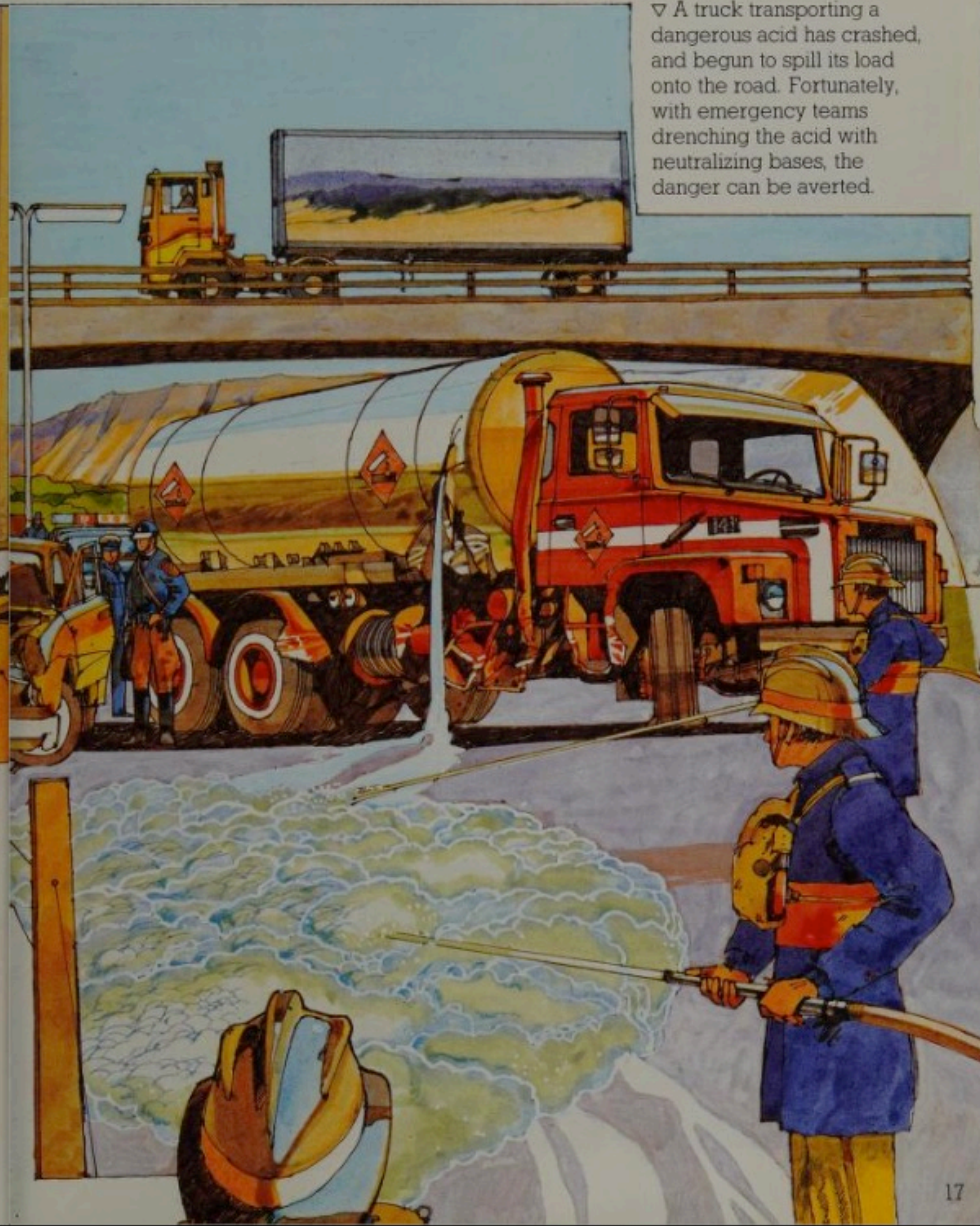
Bases neutralizing acids
How do an acid and a base neutralize each other? The two substances simply exchange partners by a chemical process with which we are already familiar: the exchange reaction.





Testing for acids and bases
Many substances react differently to acids and bases, and so can be used as "indicators." An easily made indicator is the water in which red cabbage has been boiled. It turns red when an acid (e.g. vinegar or lemon juice) is added, but bluish-green when a base (such as washing soda) is added.





▽ A truck transporting a dangerous acid has crashed, and begun to spill its load onto the road. Fortunately, with emergency teams drenching the acid with neutralizing bases, the danger can be averted.

Weak Acids

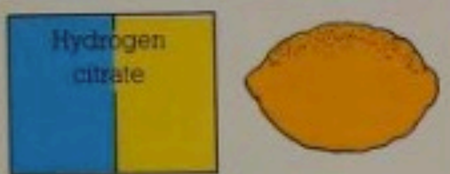
Not all acids are dangerous and corrosive. Many acids, such as Vitamin C (ascorbic acid), are essential to health. Even our own bodies produce acids, particularly to help break down food in our digestive systems.


A basket of "weak acids"

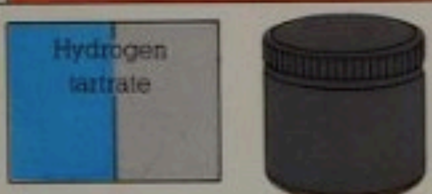
The sour taste of fruit is due to the fruit's own brand of acid. "Citrus" fruits, for example, contain citric acid. In other fruits the sour taste is often disguised by the sweetness of fruit sugars.

Acids can be thought of as hydrogen salts, with hydrogen taking the place of a metal. Acetic acid (in vinegar) can be thought of as "hydrogen acetate," lemon juice as "hydrogen citrate."

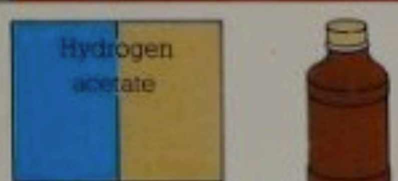
Some common weak acids



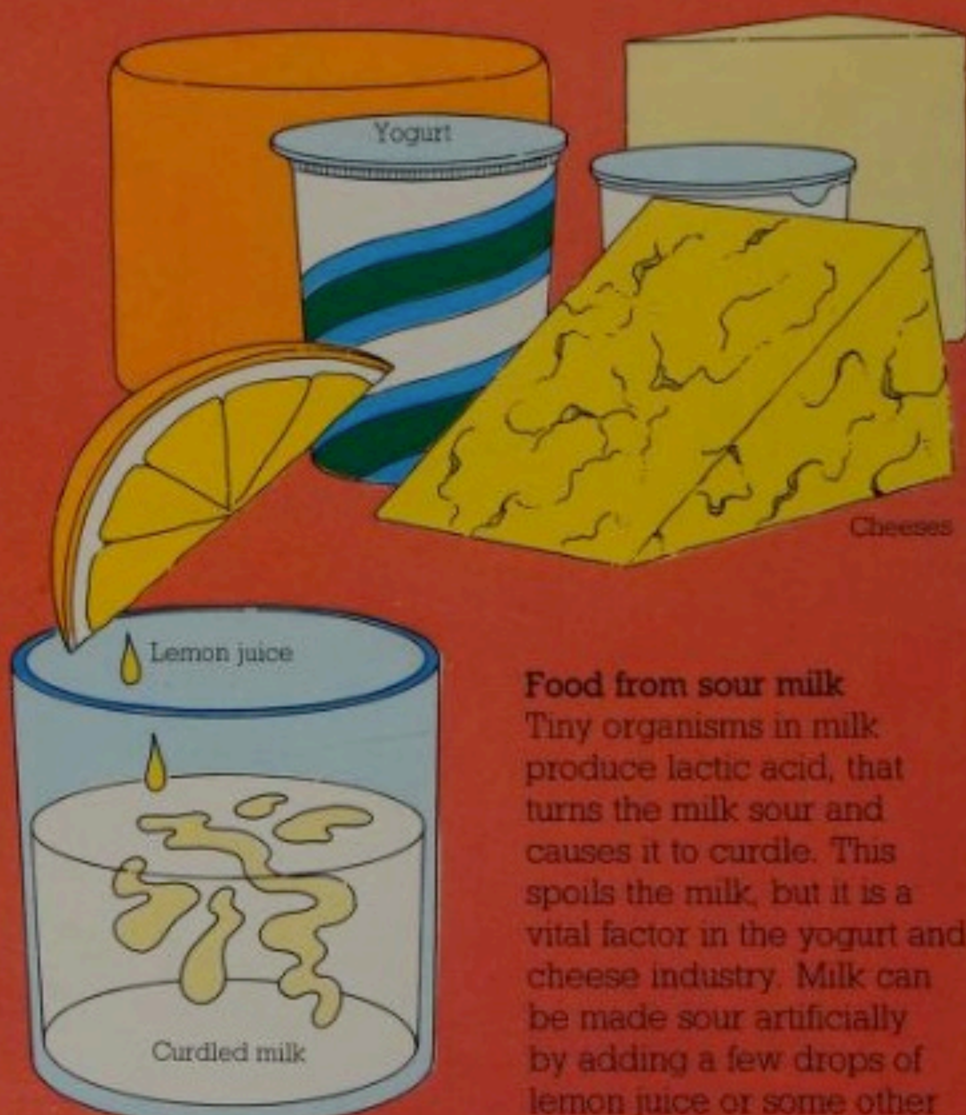
Lemon
Lemon juice, cream of tartar, and vinegar will all make bicarbonate of soda "fizz," so proving that they are acids.



Cream of tartar
The acid "hydrogen tartrate" is better known as cream of tartar. It is obtained from fermenting wine.



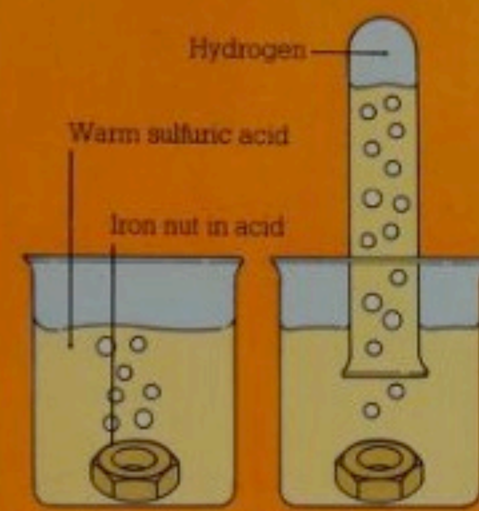
Vinegar
Vinegar, probably the commonest acid in the home, is also made from wine or beer that has gone sour.



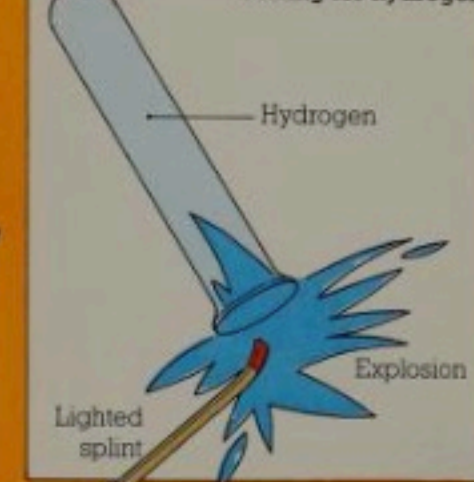
Food from sour milk
Tiny organisms in milk produce lactic acid, that turns the milk sour and causes it to curdle. This spoils the milk, but it is a vital factor in the yogurt and cheese industry. Milk can be made sour artificially by adding a few drops of lemon juice or some other mild acid.


Car battery

Strong Acids


What is happening

WARNING!
THIS IS A LABORATORY EXPERIMENT


Testing for hydrogen

A car battery contains sulfuric acid, a powerful corrosive. Even when battery acid is diluted, it will still be strong enough to rot fabric and clothing. But strangely, cold concentrated sulfuric acid will not attack iron, and so can be carried safely in iron containers. Iron dissolves in warm sulfuric acid, giving off hydrogen. The iron replaces the hydrogen in the "hydrogen sulfate," and since hydrogen is highly inflammable, a lighted splint held at the mouth of a test tube containing this gas will cause it to explode with a loud "pop."

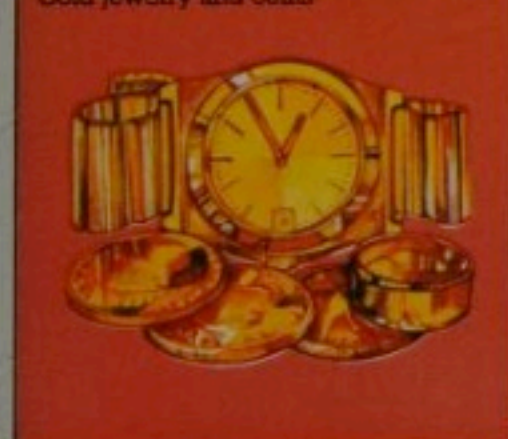
Electrochemical Series

The electrochemical series gives a good idea of which metals are the most resistant to acids. Those at the top of the list are quickly attacked, those at the bottom, hardly at all.

Jewelers use this fact to test for the purity of gold by gradually increasing the strength of the testing acid. Pure gold remains unmarked, while cheaper metals stain or corrode.

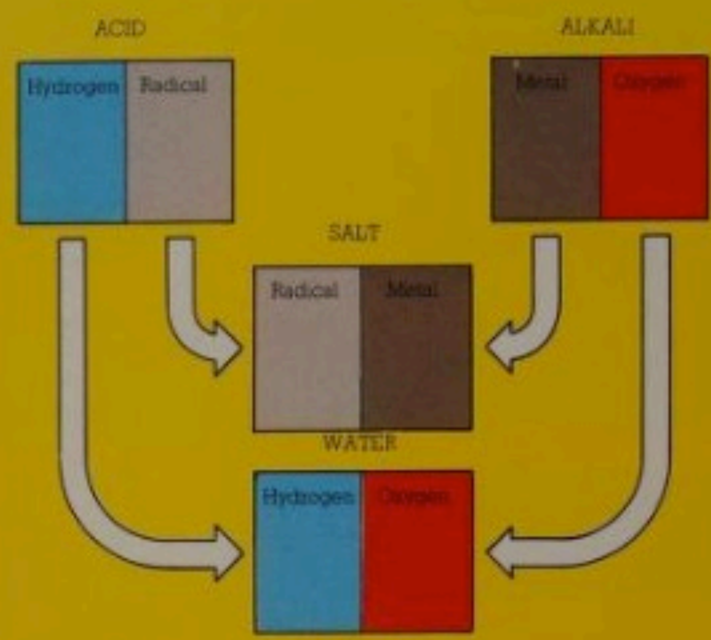
Electrochemical series

Least resistant to acids	Magnesium
	Aluminum
	Zinc
	Iron
	Lead
	Copper
	Mercury
	Silver
Most resistant to acids	Gold
	Platinum


Gold jewelry and coins

Strong Bases

Caustic soda – oven cleaner



Just as there are strong and weak acids, so too there are strong and weak bases. One very common strong base is caustic soda – sodium hydroxide. This has a powerfully corrosive effect on grease and animal matter, and is often used in cleaning agents for ovens and drains.

An alternative term for a base is an "alkali," although strictly speaking, an alkali is a base that dissolves in water. Not all bases do. Bases are the opposite to acids, with oxygen forming part or all of the "radical" component of a metal compound – for instance, magnesium oxide.

When an acid and a base neutralize each other, the acid's hydrogen and the oxygen from the base join together to form water. The remaining components combine to form a "salt." In the case of hydrochloric acid and caustic soda, the salt produced is actually common salt.

Weak Bases

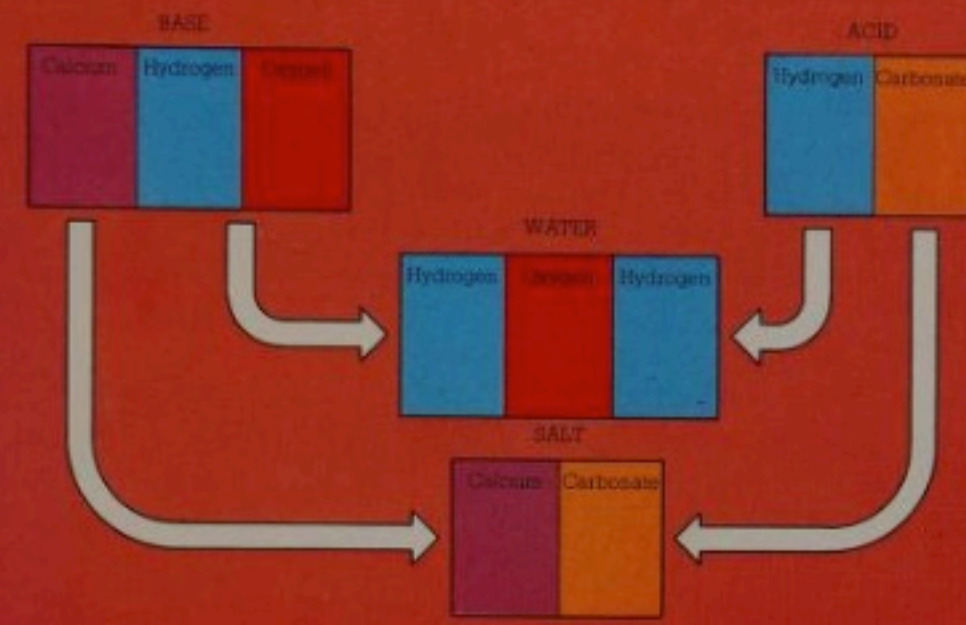
Result of eating unripe apples!

A stomach upset is often brought on by eating too much acidic food. When this happens, a weak base is needed to combat the stomach's excess acidity. "Milk of magnesia" (magnesium hydroxide) is one of the most common mild bases used for this purpose. It is able to neutralize acids in the stomach without producing any harmful side effects.

Unripe apples contain a lot of acid

Lime

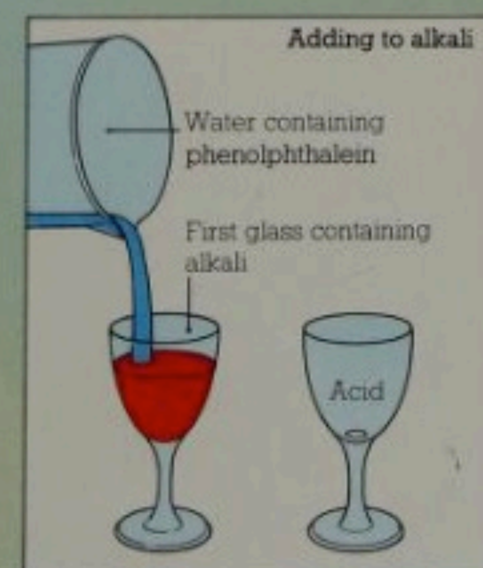
Farmers use lime (calcium hydroxide) to "sweeten" an acid soil, and make heavy, clay-laden soils more workable. Carbon dioxide in the air dissolves in water to form the very weak carbonic acid (hydrogen carbonate). The alkaline lime neutralizes any traces of carbonic acid in the earth, producing calcium carbonate (or chalk) – and some more water.



Liming fields

A Chemical Indicator

As water is poured into one glass, it appears to change into wine. When this "wine" is poured into another glass, it turns back to water! The reason is that the water jug contained a spot of phenolphthalein, which turns water bright red in the presence of an alkali. A drop of alkali in the first glass, and a drop of acid in the second is all you need.



Water is the most important substance on our planet. For life on Earth to exist, this water must be in liquid form. Considering the vast range of temperatures in the universe, from the absolute cold of the deepest regions of outer space to the incredible heat of the Sun's furnace, it is remarkable that our planet should be at exactly the right temperature for this to happen.

Water is so important to chemistry – and hence to life – because it acts as a chemical vehicle for substances taking part in reactions. We have already seen that iron will not normally rust so quickly when there is no water present; neither will it be corroded by sulfuric acid provided that it is kept dry. When substances dissolve in water, they are brought into contact with each other and can react in a way that was not possible under dry conditions.

Water, as we have discovered, is a compound of two substances – hydrogen and oxygen. (The chemical formula for water, H_2O, shows that it contains twice as much hydrogen as oxygen.) Many chemical reactions produce water. Copper oxide, for instance, reacts with hydrogen to form pure copper and water. More familiarly, bases and acids react together to form water as one of the products of chemical exchange.

Water's main ingredient, hydrogen, is the commonest substance in the universe, yet there is very little free hydrogen in the Earth's atmosphere. The reason why is not difficult to guess. During the formation of the Earth most of the available hydrogen would have been burned up in producing the water to make up the vast oceans now covering the Earth's surface.

Chemical formation of water
A glass jug of milk on a gas ring appears to "sweat." The jug is not leaking! What is happening is that hydrogen from the gas supply and oxygen in the air burn together, to form steam. This condenses as tiny droplets of water on the cold surface of the jug – a microcosm of how the oceans were formed.

◁ Liquid water is the Earth's unique feature. Millions of years ago, our planet was formed amid vast clouds of steam. In time, the Earth cooled, and the steam condensed to make the oceans. It was only then – when water was not vaporized into steam or frozen into ice – that life on Earth became possible.

Hydrogen and Water


Hydrogen-filled airship burning

Because it is the lightest known gas, hydrogen was once used to float airships and aeronautical balloons. But it happens to be also extremely dangerous, and will burn readily (sometimes explosively) in oxygen. After a couple of spectacular disasters, the idea of passenger airships was abandoned in favor of airliners. Today, gas-filled balloons (often used for weather surveys) contain helium, which is also light, and safer than hydrogen.

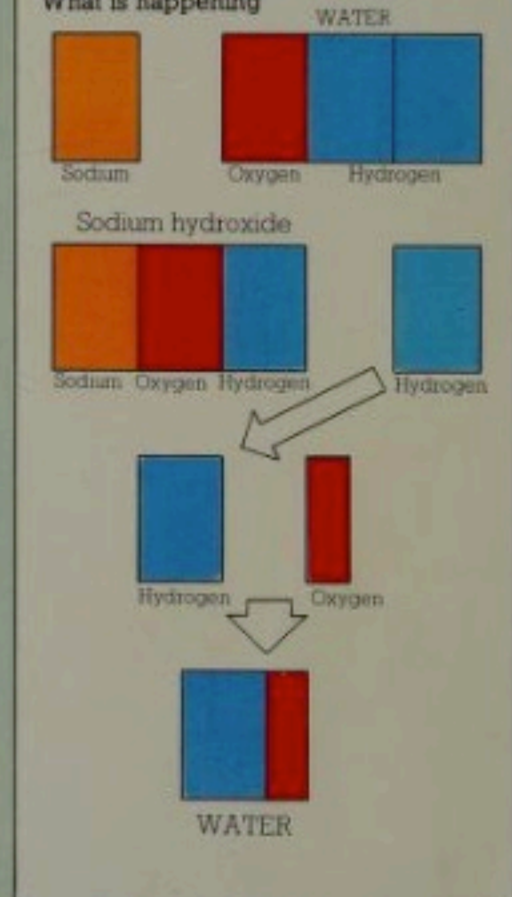
Burning Water


Sodium "burning" in water

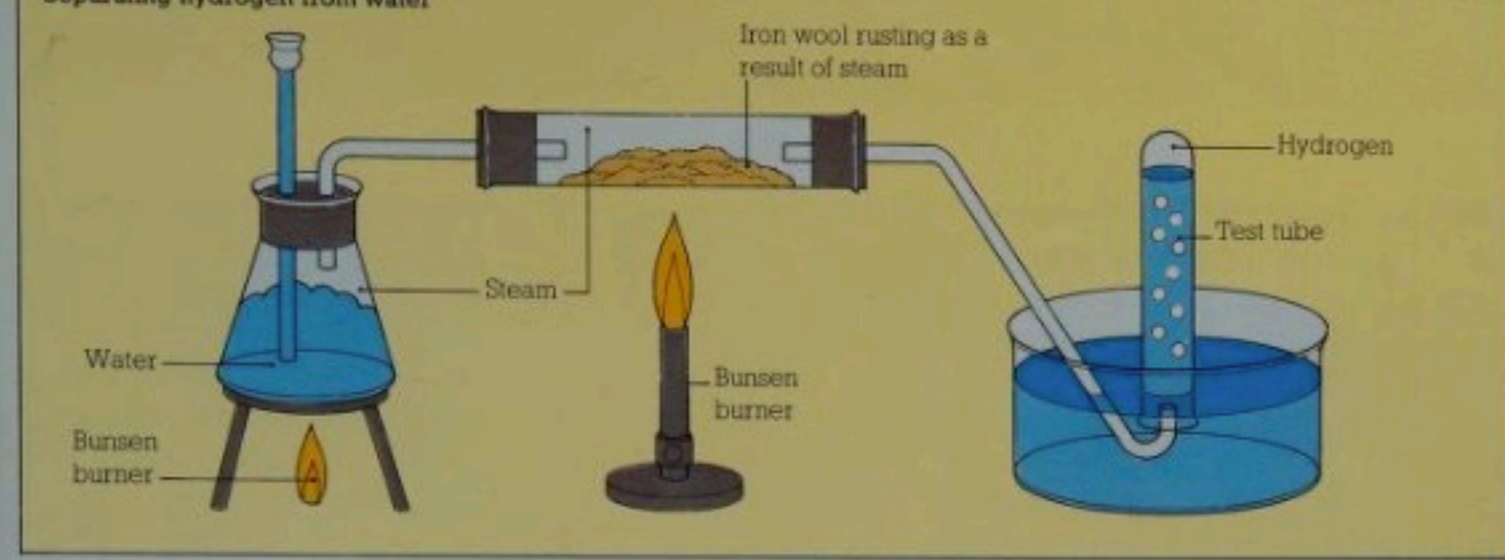
WARNING!
THIS IS A LABORATORY EXPERIMENT

Is it really possible to set water on fire? Yes. If you drop sodium into the water it will burst into flame! Sodium is a very reactive metal. It pushes half of the water's own hydrogen out of the way and takes its place (in much the same way that iron pushes copper out of copper sulfate solution). The sodium combines with the remaining hydrogen and oxygen to form sodium hydroxide. The hydrogen that is pushed out escapes as bubbles of gas, that propel the sodium round the surface of the water. Heat from the reaction sets the hydrogen alight, when it combines with oxygen in the air to form water again.

What is happening



Separating hydrogen from water

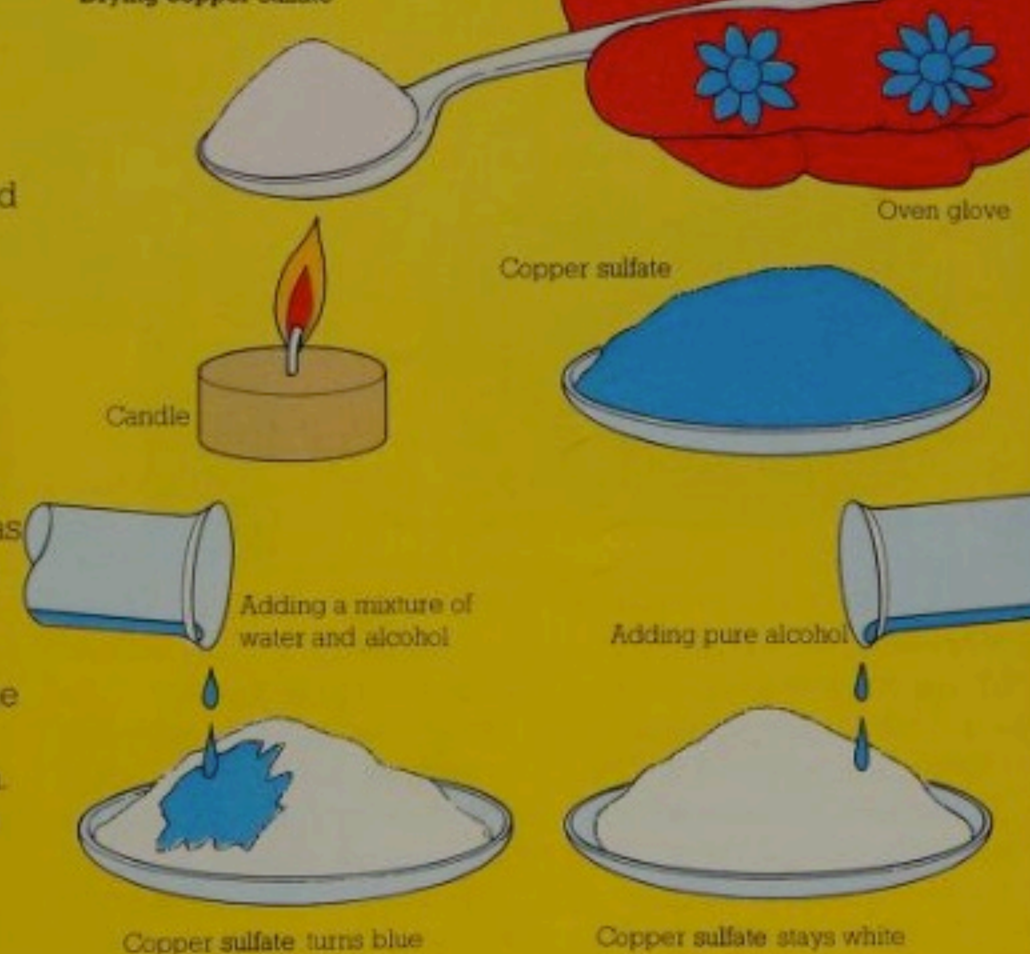


Like sodium, red-hot iron can also be used to make hydrogen from water. The water must be in the form of steam, which causes the iron to oxidize, so producing iron oxide (rust). With oxygen removed from the water, hydrogen is left behind. Hydrogen does not easily dissolve in water, and so it can be collected by bubbling it into an upturned jar of water. Effectively, the same type of replacement has occurred to produce hydrogen as in the reaction of sodium with water.

Absorption of Water

Some crystal substances, such as copper sulfate, have water locked into them. This is known as "water of crystallization," and may affect their color. If blue copper sulfate is heated to drive the water away, a whitish powder is formed – "anhydrous" (waterless) copper sulfate. This can be used to test for water. When a liquid such as pure alcohol is poured onto the powder, there is no color change. But if any water has been added to the alcohol, the copper sulfate powder will turn blue again. This is because it has taken some water from the alcohol-water mixture to re-form the blue crystals.

Drying copper sulfate



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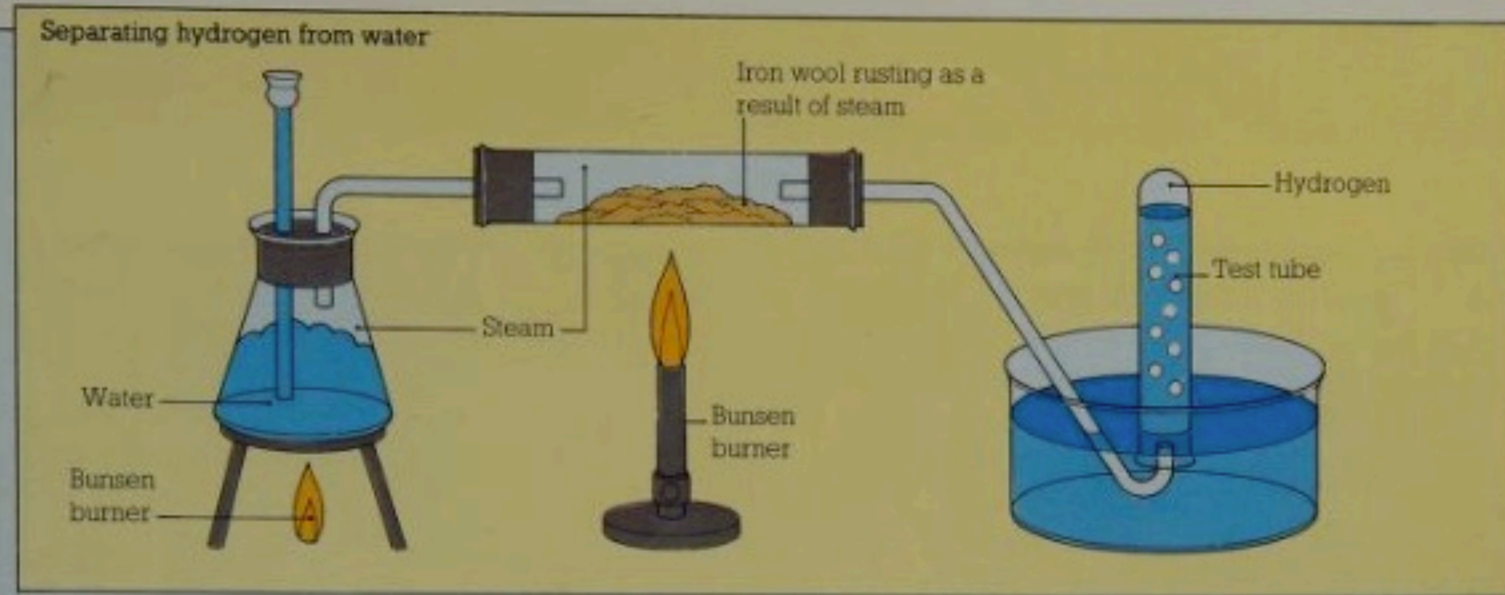

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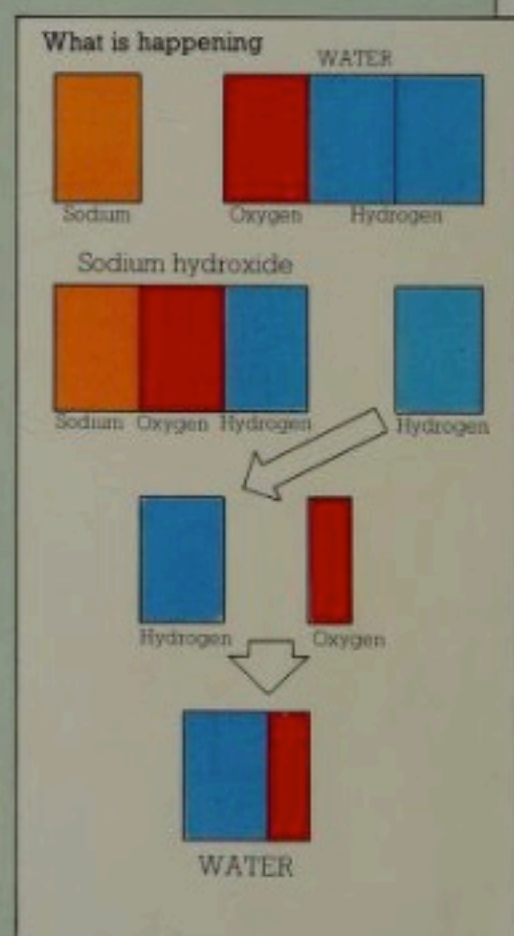

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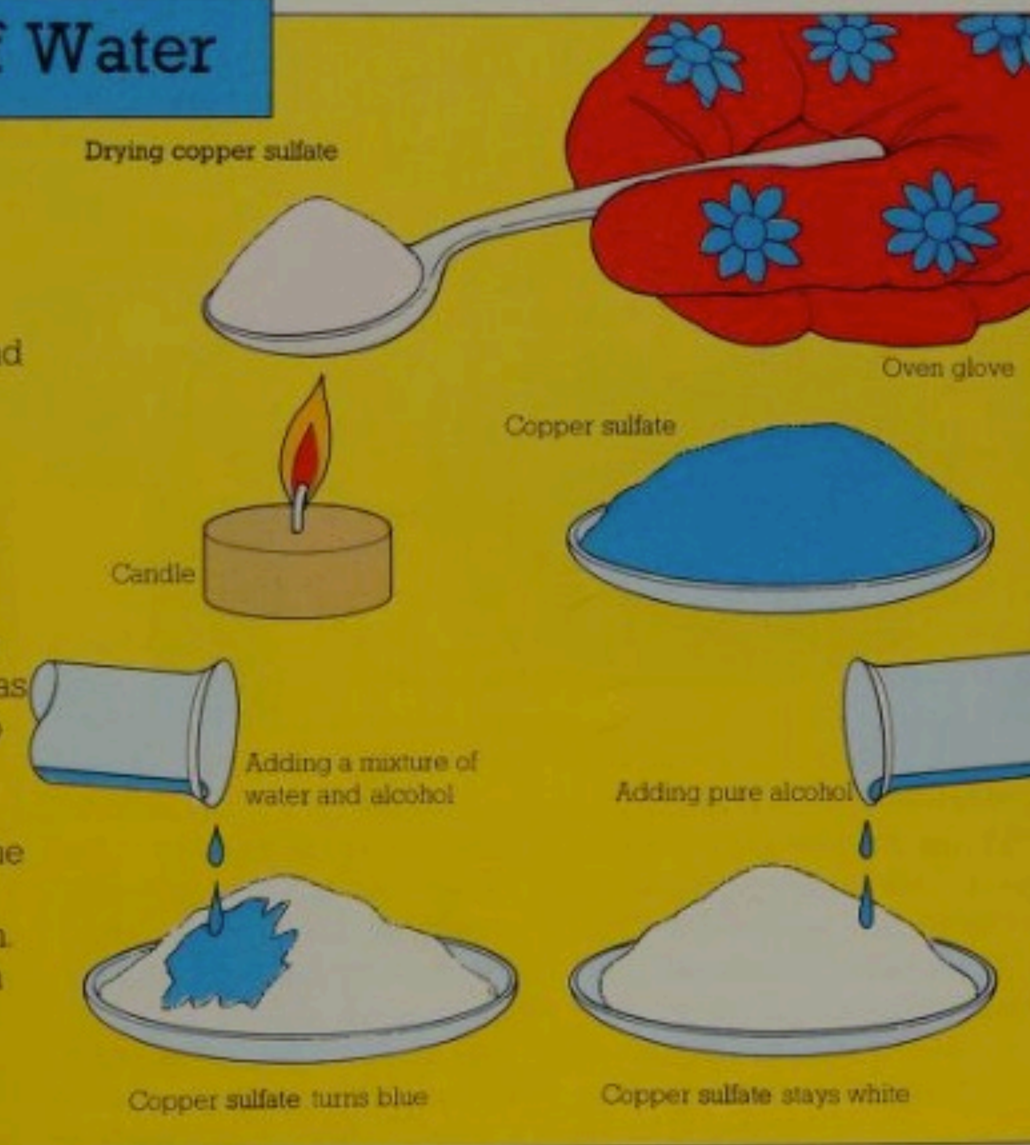


Drying copper sulfate

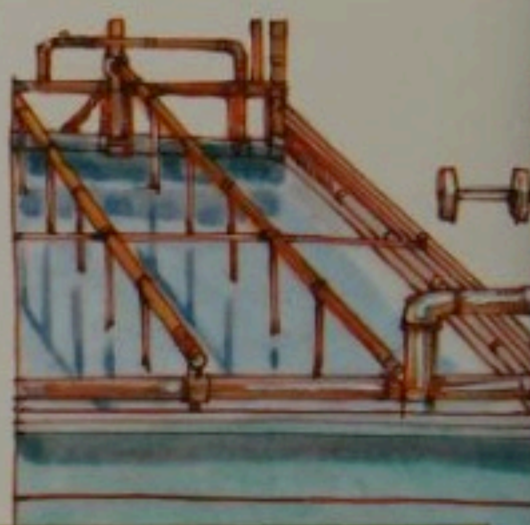
Electrolysis

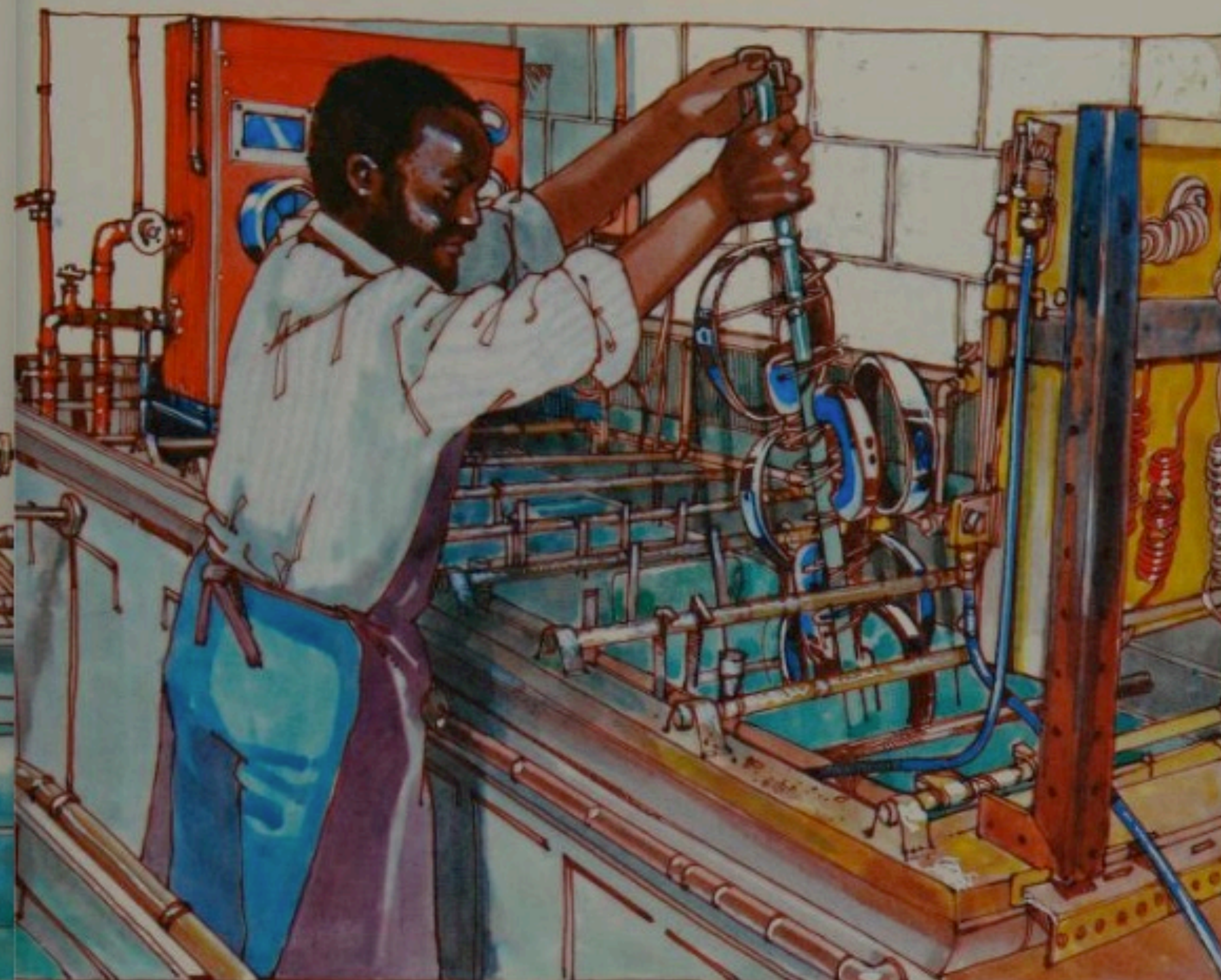
When hydrogen burns in oxygen, to form water, a great deal of energy is given out in the form of heat. If we wanted to separate the hydrogen from the oxygen again, this energy would have to be put back in some way. One method of doing this is to use electrical energy. Causing a chemical change by means of electricity is known as electrolysis.

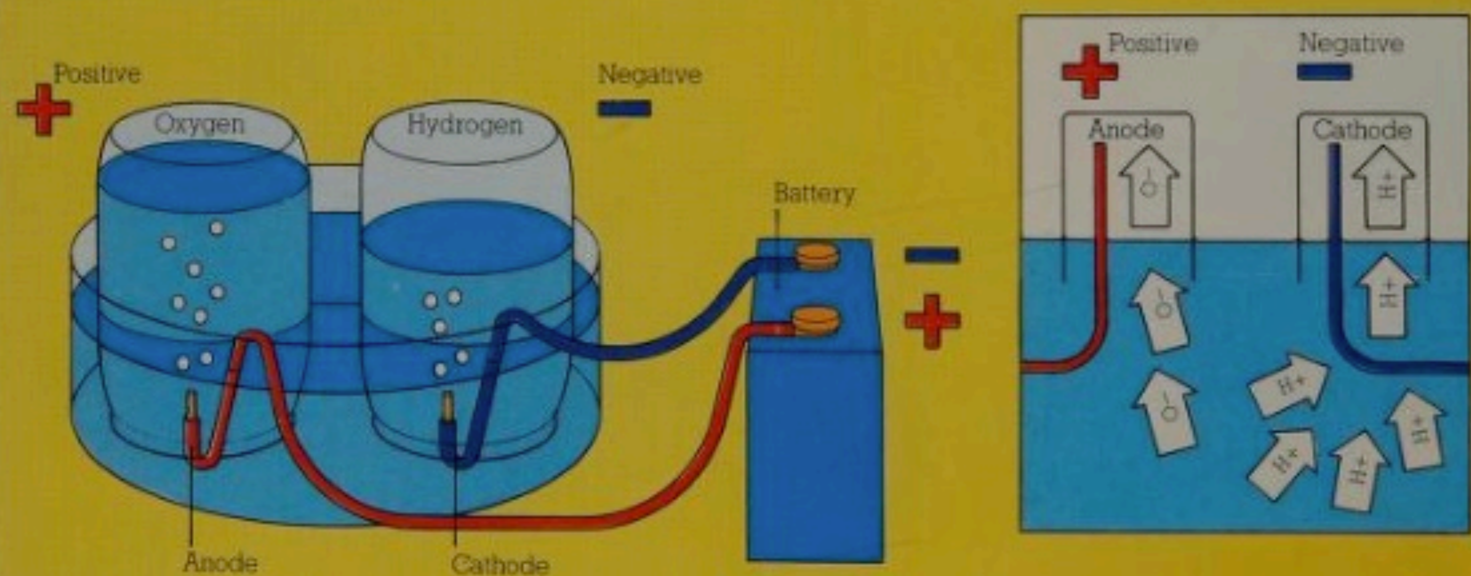
Electrolysis is a very important industrial process. It can be used for metal-plating – putting very thin coatings of expensive metals, such as silver or chromium, onto articles made of cheaper materials. This both improves their appearance and protects them from corrosion.

Another important use of electrolysis is the extraction of metals from their ores. Aluminum, one of the Earth's most common substances, is always found combined with other materials in the form of rock or clay. A hundred years ago the cost of extraction made aluminum metal more expensive than gold. Today, aluminum can be extracted by the electrolytic process and is one of our cheapest – and most useful – metals.

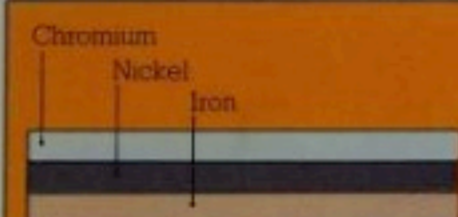
▷ In this workshop, articles made of thin sheet iron are being given a protective coating of nickel, a much more expensive metal. By using electrolysis a number of objects can be plated at the same time.







Electrolysis of water
Water can be split into its components by means of electricity. Pure water is almost totally resistant to an electric current. But if there is the slightest trace of an electrolyte present, such as sulfuric acid or salt, (which are good conductors), a current can flow through. Once the gases have begun to evolve, it is easy to see that there is twice as much hydrogen as oxygen in water. Oxygen bubbles appear at the anode (+), and hydrogen at the cathode (−). Because unlike signs attract, the oxygen ions must be negative, and the hydrogen ions positive.



Electroplating layers
Chromium cannot easily be plated onto iron direct. Instead, layers of other metals such as nickel and copper are plated onto the iron first.

When a salt dissolves in water it splits up into ions. Only substances that "ionize" can carry an electric current; they are known as electrolytes. For example, ordinary salt dissolves in water, ionizes into sodium and chloride ions, and so can carry an electric current. But sugar, does not ionize and so is not an electrolyte.

Ions carry electrical charges, and are either positive (+) or negative (−). As with magnetism, opposite signs attract and similar signs repel. In electrolysis, two metal plates, called electrodes, are dipped into the salt solution and connected to a battery. The electrode connected to the positive terminal of the battery is the "anode," and the other, attached to the negative terminal, the "cathode." Thus the positive ions are attracted to the cathode, and the negative ions to the anode.

Batteries

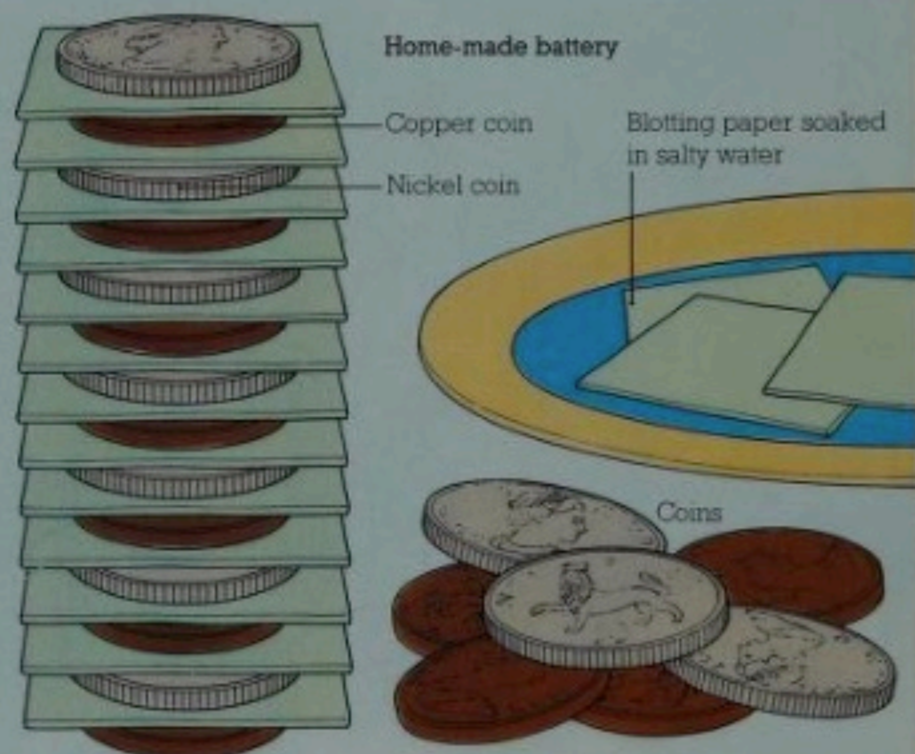
Electrolysis uses electricity to produce a chemical change. A battery, or cell, does the opposite: it uses a chemical change to produce electricity. Car batteries ("storage batteries") use both processes; electrolysis reverses the chemical changes that occur when the battery is used, and is able to "store" electrical energy.

The first batteries date from the early 1800s. They consisted of a stack of disks made of two different metals, arranged alternately, with pads of cloth soaked in salt solution in-between each layer. A pile of nickel and copper coins separated by blotting paper that has been dipped in salty water will do just as well. Electrons will flow through the pile, from nickel to copper, but cannot escape until the top and bottom are connected by a wire.

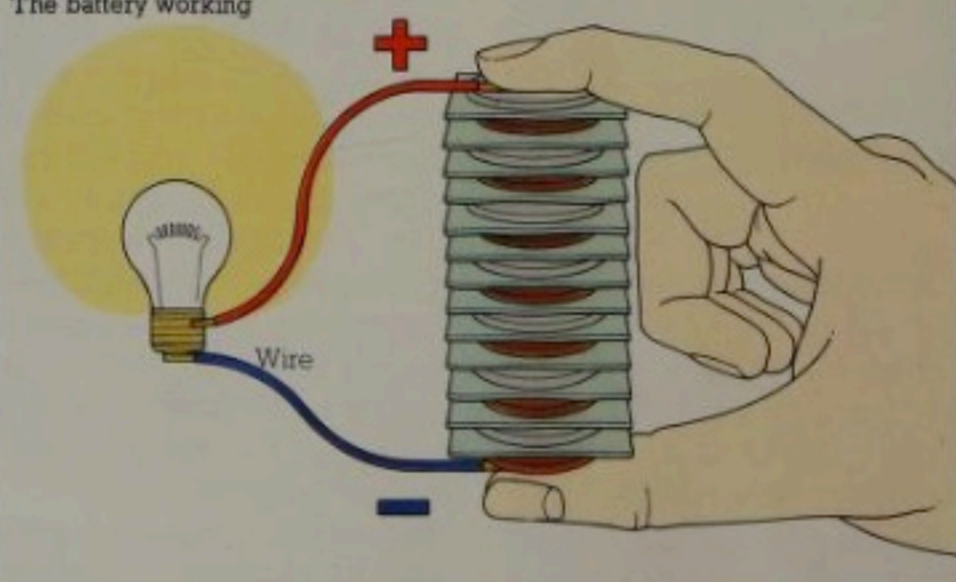
The electric current produced, once the connection is made, may be enough to light a small torch bulb rather dimly. The voltage will depend on which metals are used for the disks. The further apart the metals are in the electrochemical series (page 19), the greater the voltage. Nickel and copper produce about half a volt; aluminum and silver about two volts.

Various commercial batteries

Home-made battery

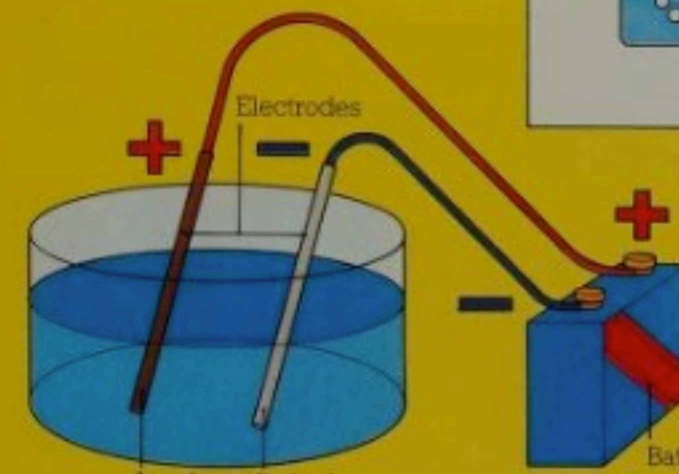


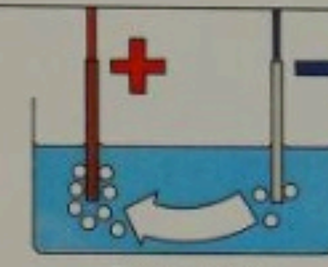
The battery working



Electroplating

Electroplated articles





Electron flow

Flow of metal ions

Articles to be plated are dipped in a silver salt solution, and connected to the cathode of a battery. The anode is made of silver, and replenishes the ions being used up from the solution.

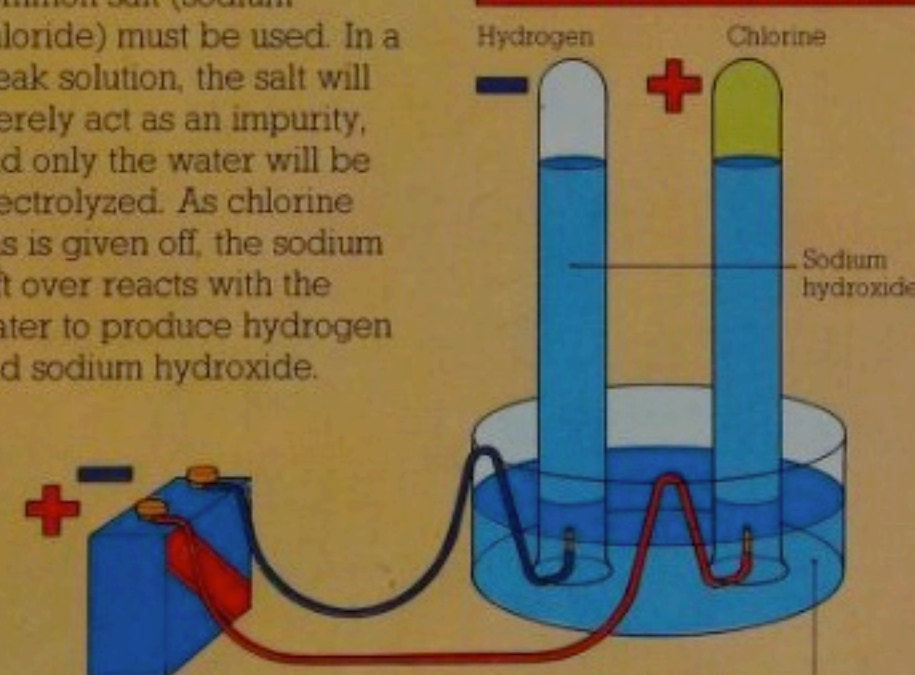
During electrolysis, metal appears to be transferred from the anode to the cathode. But the electric current (the electron flow) is actually in the opposite direction.

Making Chlorine by Electrolysis

Chlorine, used in bleach, is made commercially by electrolysis of common salt solution. For this, a concentrated solution of common salt (sodium chloride) must be used. In a weak solution, the salt will merely act as an impurity, and only the water will be electrolyzed. As chlorine gas is given off, the sodium left over reacts with the water to produce hydrogen and sodium hydroxide.

Bleach

WARNING!
THIS IS A LABORATORY EXPERIMENT

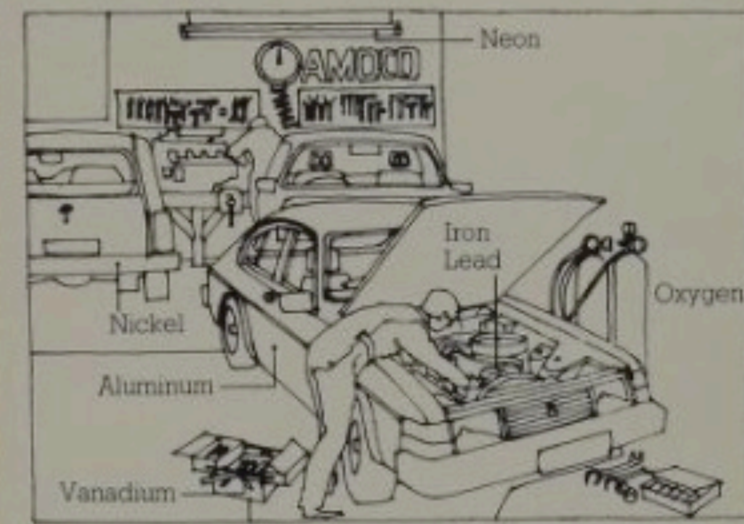


Elements

The countless objects of all kinds that surround us in our daily lives are made of materials chosen because they best serve the purpose for which the object was designed. A car's tires are made of rubber; its headlights are glass, the bodywork steel. Yet all these materials – and indeed the whole universe – are composed of the same basic substances – the elements. An element, by definition, contains only one substance, and has no other ingredients. There are 90 elements occurring naturally, although many are extremely rare. Almost everything we are likely to encounter under normal circumstances will be made from just a few dozen elements. Of these, a mere eight, including aluminum, silicon, iron and oxygen, comprise 98 percent of the Earth's crust.

Most of the materials we use are compounds – that is, they contain two or more elements combined chemically; but some, particularly metals, are elements in their own right. Aluminum, for instance, because it is light in weight and strong, is used in ship and aircraft construction. But for building engines iron is sometimes preferred; it can withstand high temperatures that would melt aluminum.

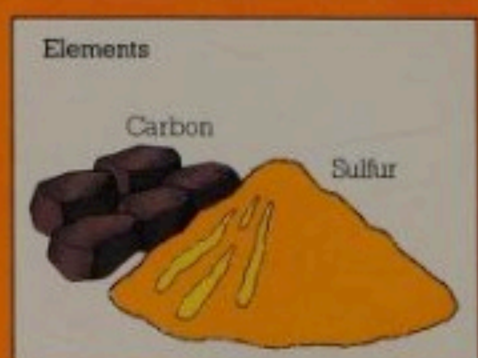
Although the majority of the elements are metals, not all the metals we meet are elements. Steel is basically iron to which other elements, including carbon, have been added. Brass and bronze are mixtures of copper with other metals, such as zinc and tin. Before the elements were known about, it was thought to be possible to make gold by mixing other metals together. Many a lifetime's work was wasted looking for the secret recipe.

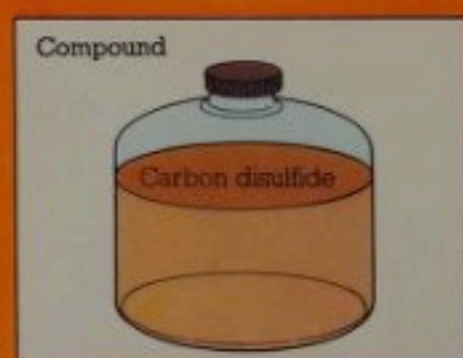


◁ In this busy garage scene, several elements can be seen in their simple state.

Combining elements

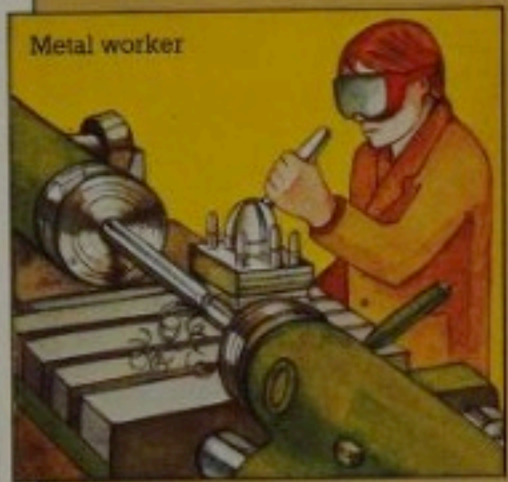
A few elements, such as oxygen, carbon and gold, occur in nature on their own. Most, however, are found in combination with other elements. There is an almost infinite number of ways in which elements can combine, and the resulting compounds seldom have any of the properties of the original elements.





For instance, when the elements carbon – a black solid – and sulfur – a yellow solid – are combined chemically, they create between them a clear, greasy liquid!

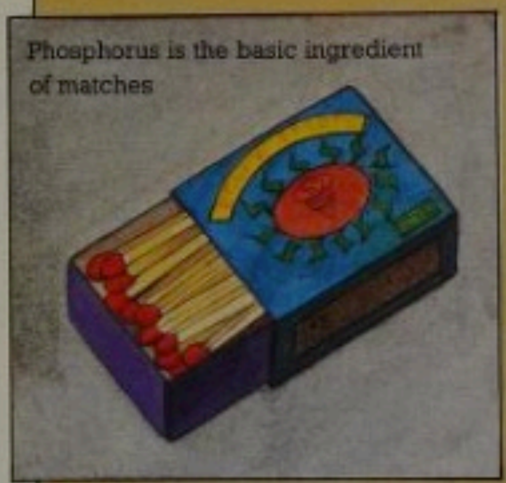
Metallic Elements


Metal worker

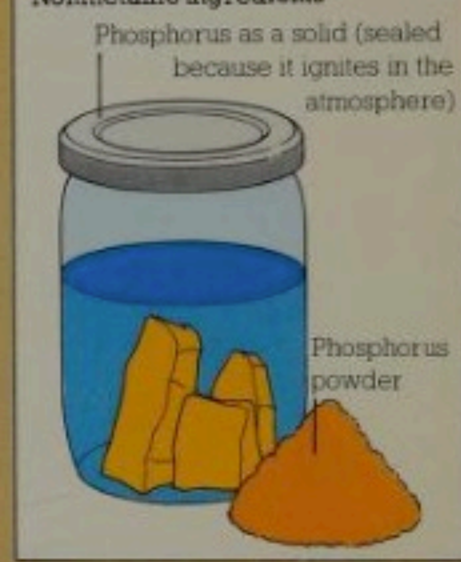
Metals are easy to recognize, but less easy to describe. The properties often vary between metals. Aluminum is light, lead heavy. Iron is hard; mercury is a liquid. Most metals are silver-gray, but not so copper or gold. One property that all metals share, however, is that they are good conductors of electricity.

Metal-bearing rocks

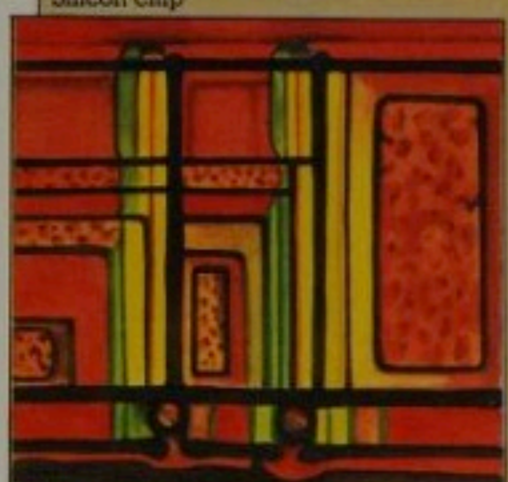

Nonmetallic Elements


Phosphorus is the basic ingredient of matches

The nonmetals are harder to recognize than the metals. Some, like boron, are "earthy" solids; others are colorless gases; bromine is a liquid. Some are even able to assume different disguises! Phosphorus can be either a luminous, yellow, waxy solid or a red powder. But nonmetals are all poor electrical conductors.

Nonmetallic ingredients


Half-way Elements

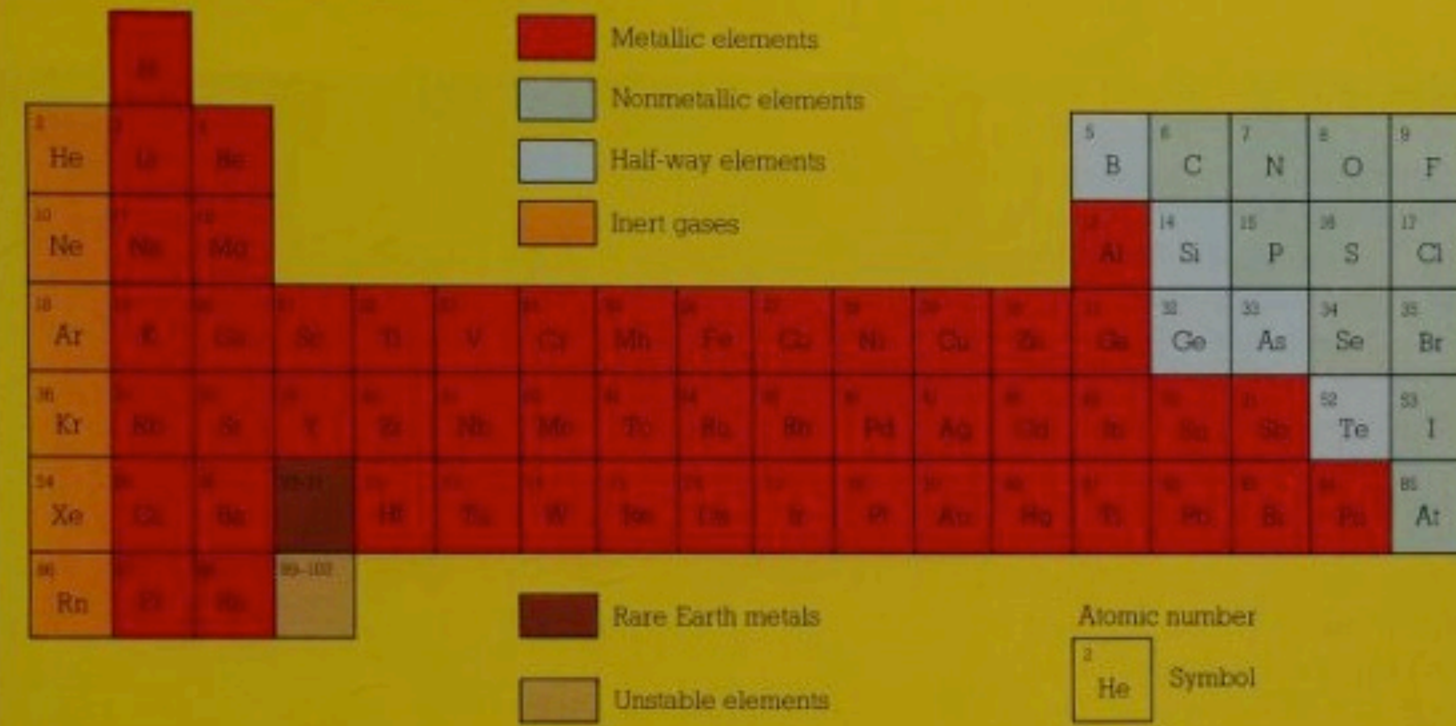
Silicon chip


Half-way elements share properties of both metals and nonmetals. Antimony, for example, has "metallic" and "nonmetallic" forms. At higher temperatures they are better conductors than metals – a property that makes them important for the electronics industry. Silicon, the basis of the microchip, is the best known half-way element.

Metallic antimony crystal


Nonmetallic antimony powder


The Periodic Table



If all the elements are arranged by order of the weight of their individual atoms, a fascinating fact emerges. The properties of the elements – physical and chemical – follow a definite pattern that recurs like the notes on a piano keyboard. The Periodic Table (above) shows the elements arranged in this way. The left-hand column contains those gases such as helium and neon that never combine with any other element. Next to them are the reactive metals, such as sodium and potassium, which dissolve in water to form hydroxides. On the far right, the column includes the very important reactive nonmetals – chlorine, iodine and fluorine. In the center are the durable metals, such as copper, silver and gold, used since ancient times for coinage and jewelry.

The periodic table

ELEMENT	SYMBOL	ATOMIC NO.	ELEMENT	SYMBOL	ATOMIC NO
Actinium	Ac	89	Mercury	Hg	80
Aluminum	Al	13	Molybdenum	Mo	42
Americium	Am	95	Neodymium	Nd	60
Antimony	Sb	51	Neon	Ne	10
Argon	Ar	18	Neptunium	Np	93
Arsenic	As	33	Nickel	Ni	28
Astatine	At	85	Niobium	Nb	41
Barium	Ba	56	Nitrogen	N	7
Berkelium	Bk	97	Nobelium	No	102
Beryllium	Be	4	Osmium	Os	76
Bismuth	Bi	83	Oxygen	O	8
Boron	B	5	Palladium	Pd	46
Bromine	Br	35	Phosphorus	P	15
Cadmium	Cd	48	Platinum	Pt	78
Calcium	Ca	20	Plutonium	Pu	94
Californium	Cf	98	Polonium	Po	84
Carbon	C	6	Potassium	K	19
Cerium	Ce	58	Praseodymium	Pr	59
Cesium	Cs	55	Promethium	Pm	61
Chlorine	Cl	17	Protactinium	Pa	91
Chromium	Cr	24	Radium	Ra	88
Cobalt	Co	27	Radon	Rn	86
Copper	Cu	29	Rhenium	Re	75
Curium	Cm	96	Rhodium	Rh	45
Dysprosium	Dy	66	Rubidium	Rb	37
Einsteinium	Es	99	Ruthenium	Ru	44
Erbium	Er	68	Samarium	Sm	62
Europium	Eu	63	Scandium	Sc	21
Fermium	Fm	100	Selenium	Se	34
Fluorine	F	9	Silicon	Si	14
Francium	Fr	87	Silver	Ag	47
Gadolinium	Gd	64	Sodium	Na	11
Gallium	Ga	31	Strontium	Sr	38
Germanium	Ge	32	Sulfur	S	16
Gold	Au	79	Tantalum	Ta	73
Hafnium	Hf	72	Technetium	Tc	43
Helium	He	2	Tellurium	Te	52
Holmium	Ho	67	Terbium	Tb	65
Hydrogen	H	1	Thallium	Tl	81
Indium	In	49	Thorium	Th	90
Iodine	I	53	Thulium	Tm	69
Iridium	Ir	77	Tin	Sn	50
Iron	Fe	26	Titanium	Ti	22
Krypton	Kr	36	Tungsten	W	74
Lanthanum	La	57	Uranium	U	92
Lawrencium	Lr	103	Vanadium	V	23
Lead	Pb	82	Xenon	Xe	54
Lithium	Li	3	Ytterbium	Yb	70
Lutetium	Lu	71	Yttrium	Y	39
Magnesium	Mg	12	Zinc	Zn	30
Manganese	Mn	25	Zirconium	Zr	40
Mendelevium	Md	101			

Atoms and Molecules

An atom is the tiniest part of an element that can exist and still have the properties of that element. Every element has its own kind of atom. The simplest atom is that of hydrogen – of which most of the universe is composed. During the evolution of a star, under tremendous pressure and intense heat, hydrogen atoms become welded together in a way that is not possible in chemistry. First of all, helium atoms are formed; and then, as the star begins to explode, these helium atoms "fuse" together, creating even more elements, before being hurled out into space to become planets like our own.

Besides being the building bricks of the universe, atoms are tiny solar systems in themselves, having a central nucleus surrounded by a cloud of electrons, rather like planets orbiting the Sun. But atoms are so small that there are as many of them in a full stop as there are people in the world! Even more surprising, perhaps, is the fact that atoms consist almost entirely of empty space. If our diagram of the hydrogen atom were drawn to scale it would have to be the size of a football pitch, with a minute speck, no bigger than a pinhead, on the center spot, representing the nucleus. Somewhere on the touch line would be an even tinier speck representing the electron. Everything in-between would be empty space.

Chemistry is, essentially, the study of the behavior of the electrons of an atom, and chemical energy the result of electron activity on the outside of the atom. Our look at chemistry began with the human race's first experience of chemical change – fire – and ends with the power of the future – nuclear energy. Nuclear energy is the result of changes within the atomic nucleus itself. Whereas in a chemical reaction atoms of different elements combine, a nuclear reaction actually changes one element into another, releasing enormous energy in the process.

▷ In AD 1054 a new star appeared, so bright that it could be seen even by day. Two years later, it had vanished altogether, leaving only a faint wisp, the celebrated Crab Nebula, and hurling millions of atoms into space.

Atomic charges

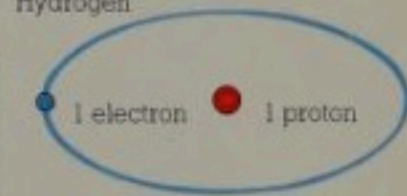
The mass of an atom is in the nucleus, and made up of protons (positively charged particles) and neutrons (carrying no charge). The orbiting electrons have a negative charge, but almost no mass.

	Proton	Neutron	Electron
	●	●	●
Charge	+1	Zero	−1
Mass	1	1	Zero

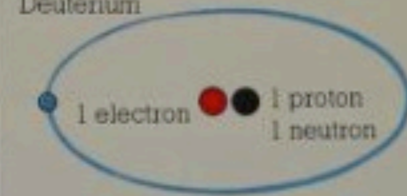
Atoms

A simple hydrogen atom consists of a single proton (+) orbited by an electron (−). Rarer forms of hydrogen, such as deuterium and tritium, also have neutrons in their nuclei.

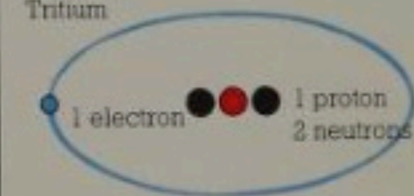
Hydrogen



Deuterium



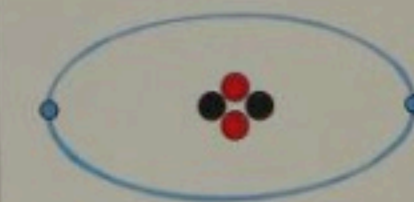
Tritium



Helium

Helium has two protons in the nucleus, and two electrons in orbit. Most helium atoms also contain two neutrons.

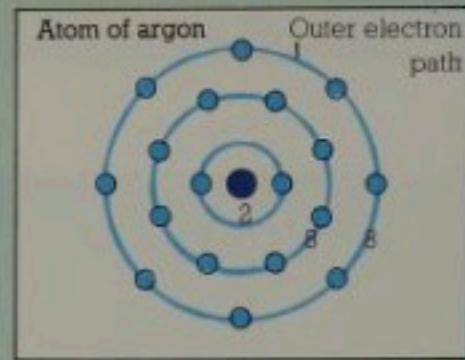
2 electrons
2 protons
2 neutrons

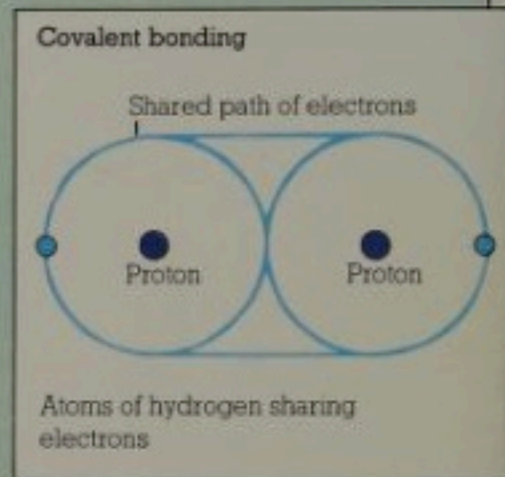


Sharing Electrons

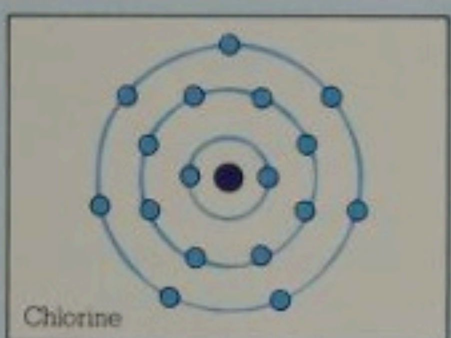
Unlike other sub-atomic particles, electrons are easily detached from the atom. The picture on your TV set is produced by firing electrons at the screen, which has been coated with zinc sulfide.

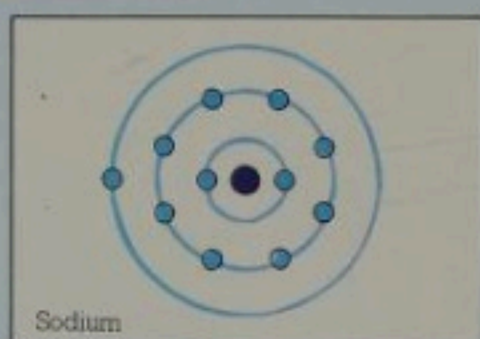
How many electrons an element has is important. The electrons in an atom try to arrange themselves into orbits of eight, but with just two electrons in the inner orbit. Argon has 18 electrons, two in its inner orbit, and eight in each outer – the ideal arrangement. Argon is thus perfectly balanced and refuses to combine with any other element. Hydrogen has only one electron, and so two hydrogen atoms readily combine to allow a single orbit of two electrons. This is called covalent, or shared, bonding.

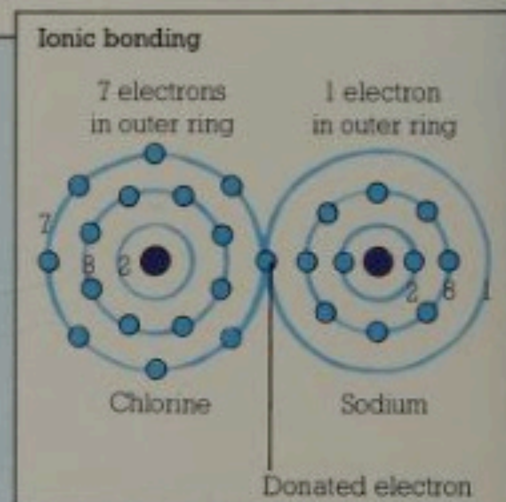




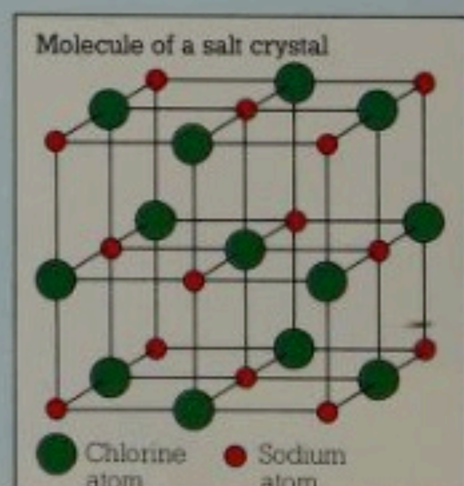
Donating Electrons



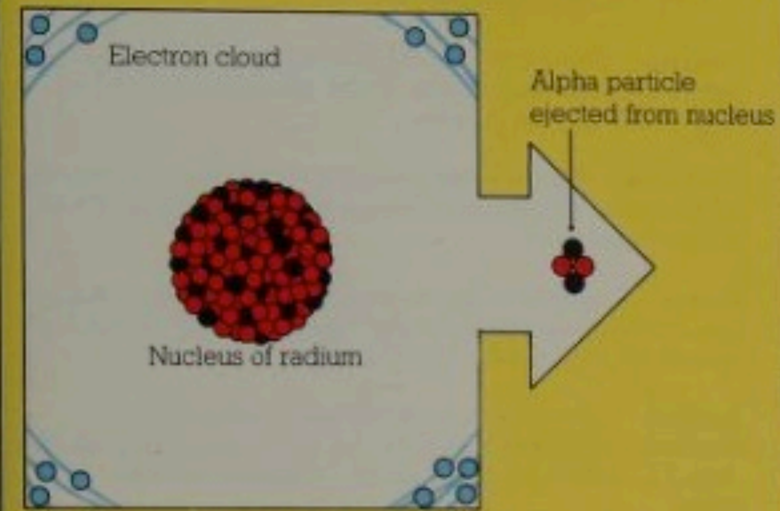


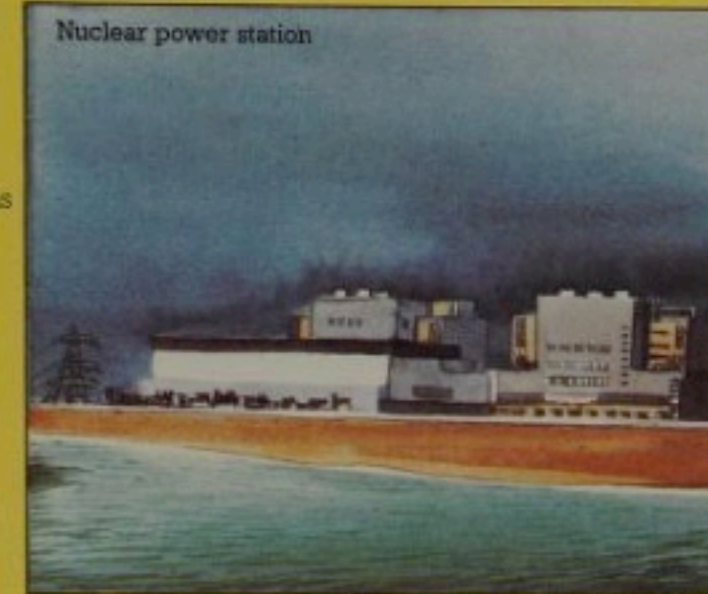


If the outer electrons of two elements add up to eight, the elements should react together easily. Chlorine has 17 electrons: two in its inner orbit, eight in the next, and seven in the outer orbit. Sodium has 11 electrons: two, then eight, but only one in its outer orbit. Atoms of chlorine and sodium combine to form molecules of sodium chloride. Now the atoms of both elements have eight electrons in their outer orbits, sodium having lost one electron and chlorine having gained one. This is called ionic bonding. The cubic structure of a salt crystal is due to the regular arrangements of its sodium and chlorine atoms.



Splitting the Atom

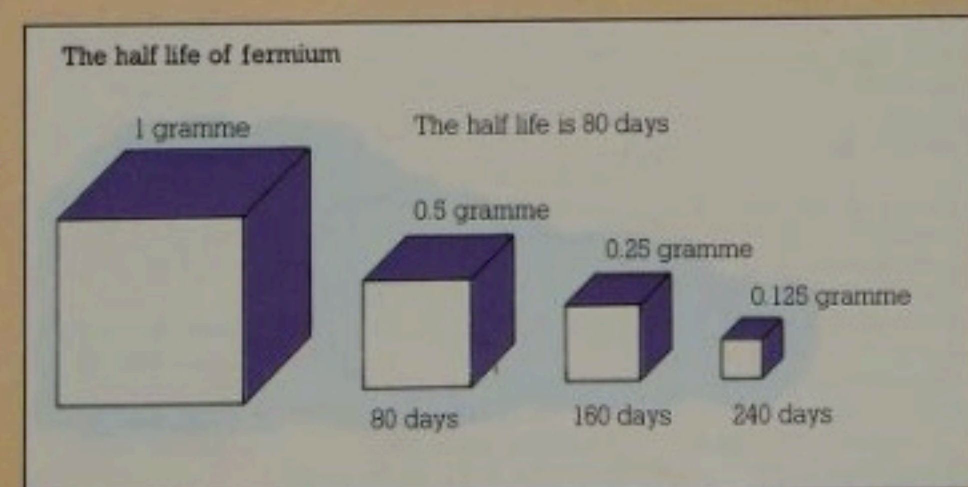




"Radioactive elements" are those which have a naturally unstable atomic nucleus. In the case of radium, two protons and two neutrons bonded together – an "alpha particle" – break away from the nucleus. The radium atom, having lost the alpha particle, now has the atomic structure of another element – radon. Other elements – uranium, for example – break up in a similar way, but also release huge amounts of energy as they do so. This energy is harnessed in nuclear power plants.

Half-life

Radioactive elements are ones in which the atoms break up, changing into atoms of other elements. The time taken for half the original element to disappear is called the half-life. The man-made element fermium has a half-life of 80 days. Thus, if a gramme of fermium were made today, less than one-sixteenth of a gramme would be left at the end of a year. The half-life can be very useful. By measuring the amount of radioactive carbon left in fossil remains, or other matter that was once alive, scientists can determine their age.



Glossary

Acid A substance containing hydrogen that can be replaced by a metal to form a salt. The opposite kind of substance to a base.

Atom The smallest part of an element that can exist and still have the properties of that element. Strictly speaking, the smallest part of an element that can take place in a chemical process.

Base A substance which reacts with an acid to produce a salt and water only. Bases which dissolve in water are called alkalis.

Compound A substance which is a chemical combination of more than one element.

Electrolysis Causing a chemical change by passing an electric current through a liquid.

Electron A negatively charged atomic particle, normally orbiting the nucleus of an atom.

Element A substance which contains only one kind of atom. All the elements are listed on page 33.

Indicator A substance which can detect certain chemical changes by turning a particular color, e.g. phenolphthalein turns red in the presence of an alkali.

Molecule The smallest particle of a substance that still has the chemical properties of that substance.

Neutron A particle at the nucleus of an atom, with a mass of 1, but no electrical charge.

Nucleus The central core of an atom, containing all the atom's neutrons and protons; almost all the atom's mass is concentrated in the nucleus.

Oxidation The chemical process of combining a substance with oxygen. Rusting, bleaching, and even breathing are all forms of oxidation.

Proton A particle at the nucleus of an atom, with a mass of 1 and a positive electrical charge. The number of protons in an atom is the element's atomic number.

Radical A group of atoms with distinct features when combined with other elements, but which do not exist on their own, e.g. "sulfate," a combination of oxygen and sulfur atoms.

Reactive Readily undergoing a chemical change, e.g. sodium and chlorine are both very reactive, lead and nitrogen are not. Helium and similar gases are totally unreactive.

Salt A chemical compound formed when the hydrogen of an acid has been replaced by a metal. Salts take their names from the metal and acid which form them, e.g. lead nitrate, from lead (metal) and nitric acid.

Index

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People are always asking questions about the world around them. What happens when things burn? Why does it rain? What are volcanoes? How did the sun and stars come into being, and what are they made of? The *Science World* is a new eight-book series that shows how the different sciences discover answers to these and many other searching questions. Each book is vividly illustrated, and has a clearly-written expert text, to bring out the basic principles of each subject, using examples taken from everyday life and simple experiments.

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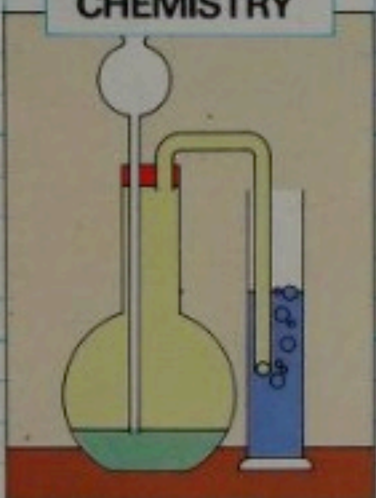

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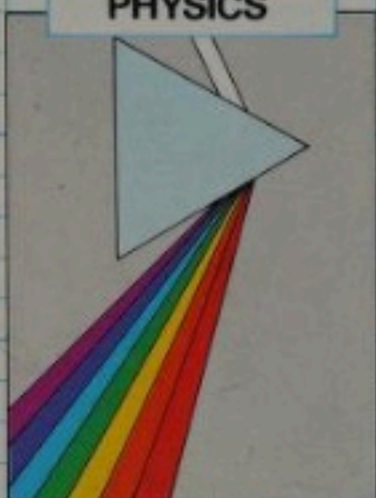

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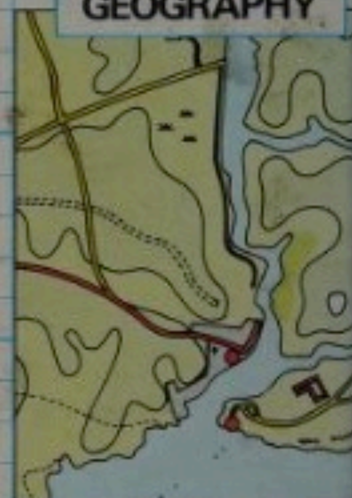

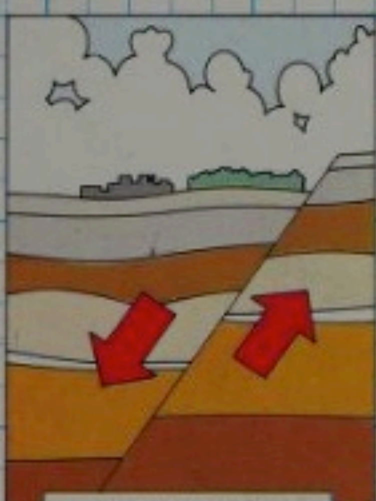

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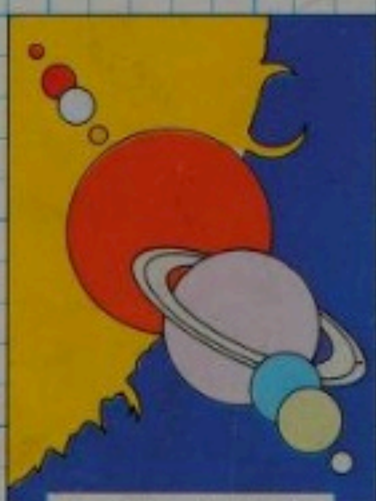

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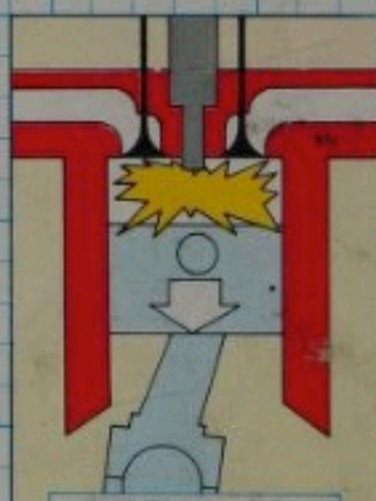

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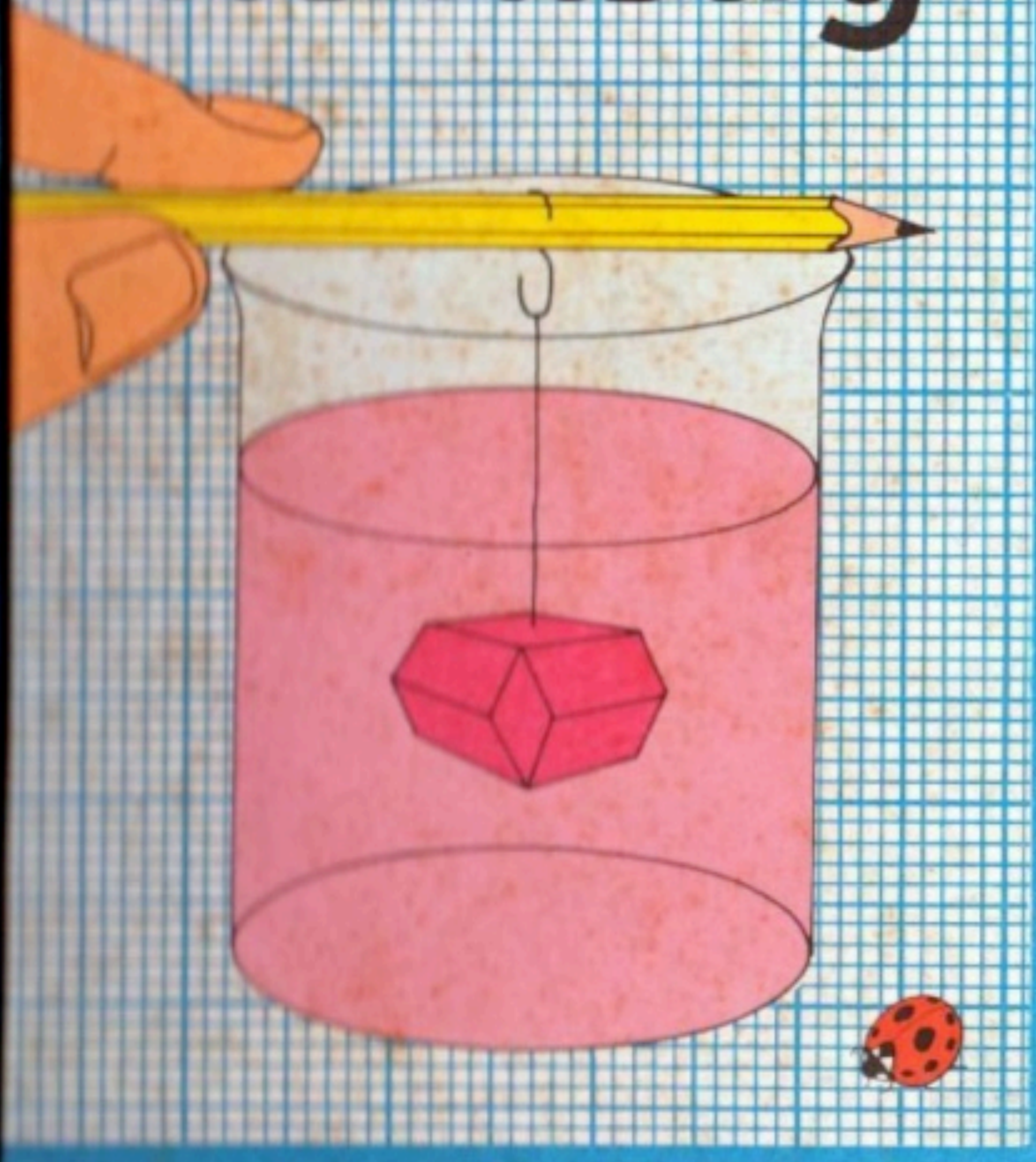
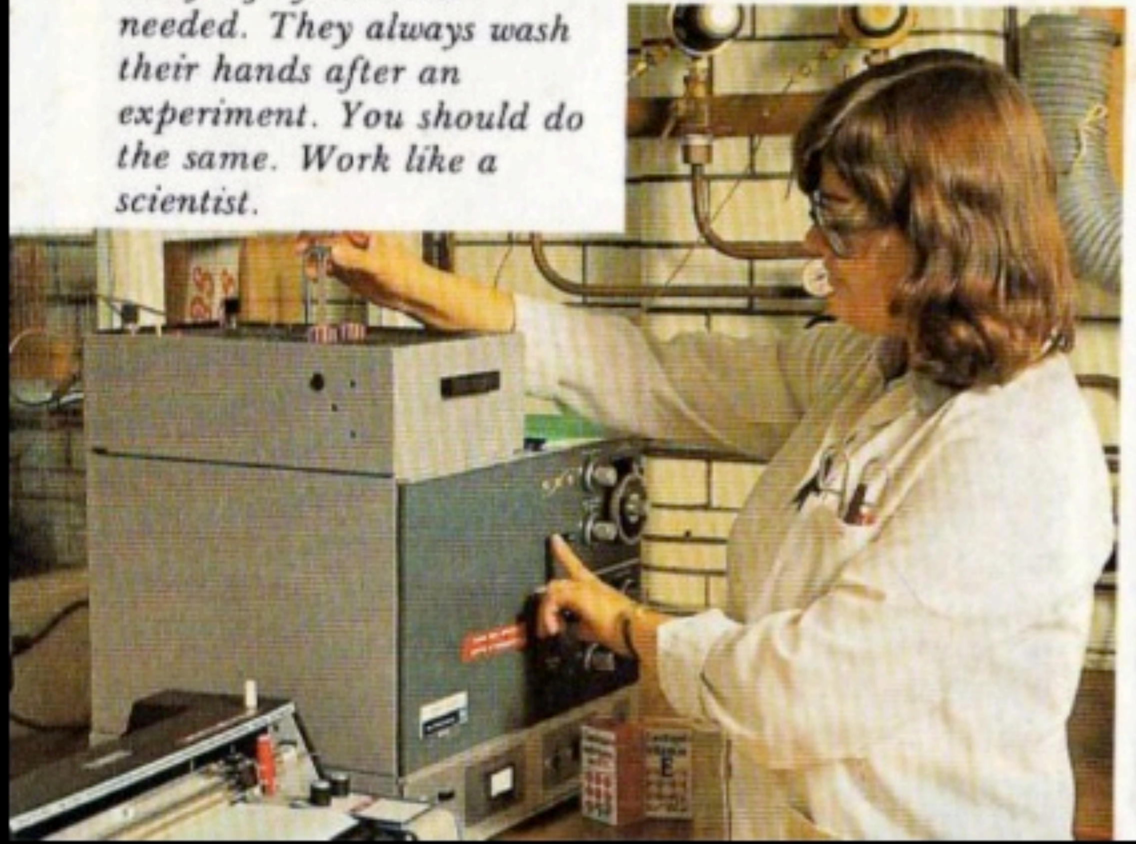


Science experiments

The ideas and experiments in this book introduce you to the science of chemistry. The experiments are safe, BUT, as you read the book and try the investigations, remember you MUST be careful. All experiments are dangerous if carried out without thought or without reading the instructions and following them exactly.

Chemists, like all scientists, do not take any risks. They always check that the materials and equipment they use are handled with care and put away safely when not needed. They always wash their hands after an experiment. You should do the same. Work like a scientist.



Children don't need expensive chemistry sets or dangerous chemicals to begin to explore sound scientific principles.

This book presents chemistry as it affects our daily lives and, using household items, encourages children to make scientific investigations and observations. The experiments are fun – from sugar crystals to moving mothballs, and baking to growing crystal gardens.

Acknowledgments

The author and publishers would like to thank the following for extra material used in this book. Page 7 (bottom), Pilkington Brothers Ltd; pages 16 and 30, Popperfoto; pages 18 and 50, Alan Hutchison Library; pages 21 and 48, G I Bernard and Dr J A L Cooke, Oxford Scientific Films; page 23 (top), John Paull; page 34, The Wiggins Teape Group Ltd; page 49, Smith and Nephew Pharmaceuticals Ltd; and for their co-operation in the taking of photographs for the front endpaper and page 6 (top), Fisons Pharmaceuticals Ltd, Loughborough.

First Edition

Simple Chemistry

written by JOHN and DOROTHY PAULL
illustrations by PETER ROBINSON
photographs by TIM CLARK

Ladybird Books Loughborough

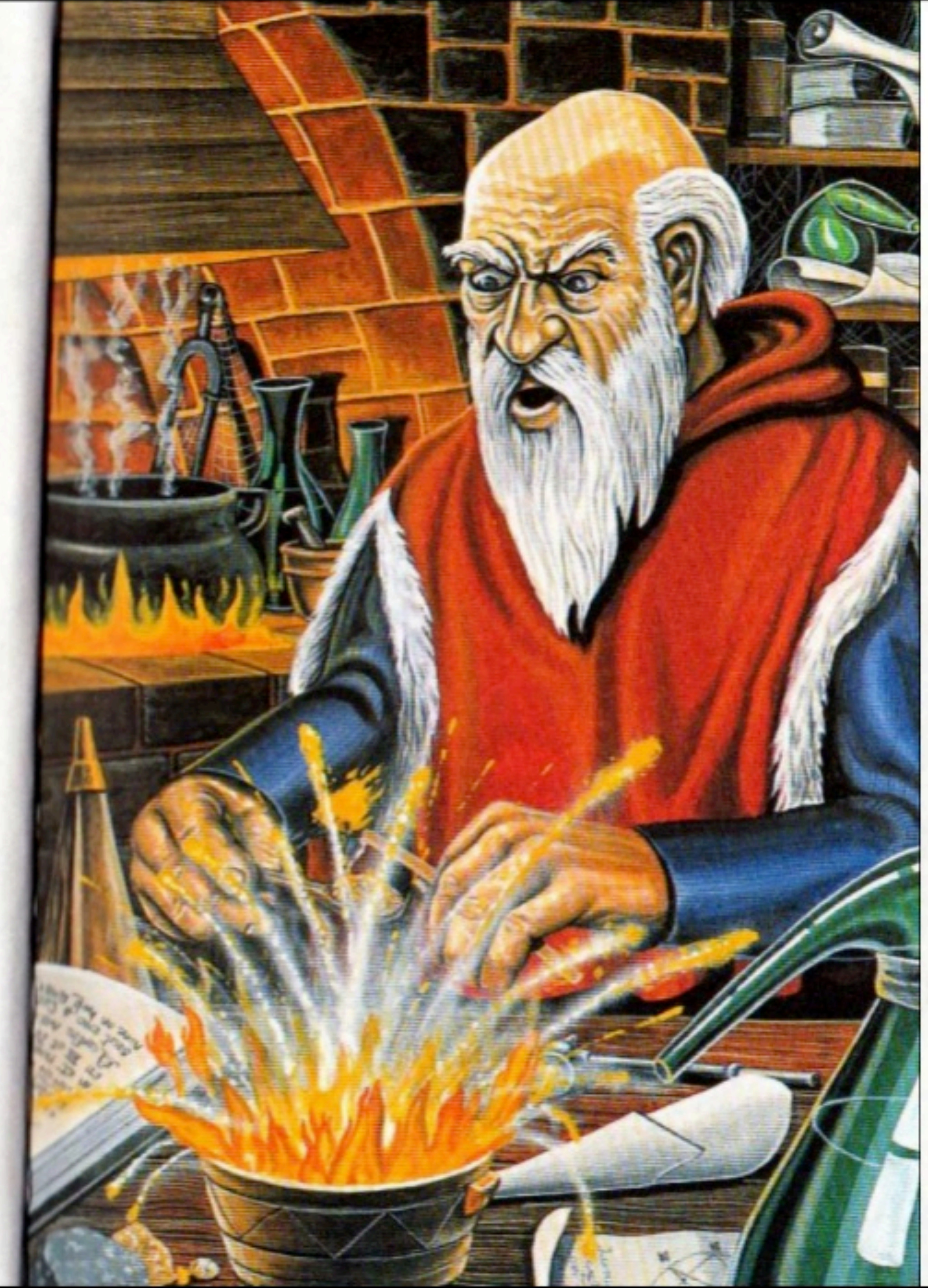
The beginning of chemistry

Chemistry is not a new science. Just when it started, nobody quite knows because its history is clouded by the mists of time. Medieval artists have pictured the first chemists as wizened old men stirring mixtures of bats' brains, frogs' eyes, and lizards' tongues in bubbling cauldrons, muttering strange and peculiar spells.

The first chemists were called *alchemists*. The word *alchemy* means the ancient art of trying to change ordinary metals into gold. About six thousand years ago, some priests discovered how to produce gold by melting gold ore. They also made medicines from herbs and roots of plants which they gathered in the forests. In 1144 AD, Robert of Chester revealed the priests' secrets when he published many of their recipes and their instructions on how to make gold. Alchemy became very popular as people experimented with the ideas in Robert's book. Soon almost every village had its own alchemist, often an eccentric old person living alone, convinced he or she could perform magic.

These people relied on superstitions and sold concoctions to cure all kinds of ailments, from warts to bad wounds. They also made poisons from plants, to kill vermin that destroyed crops. They wrote and sold spells to improve the harvest, and bottled mysterious potions that promised eternal youth to the drinker.

It wasn't just the common folk who believed in the alchemist. Even Queen Elizabeth I had a full time alchemist in her court – but he couldn't have been very successful because the records show that he ended up in the Tower of London. Much of the intrigue and 'hocus-pocus' of the alchemists' work disappeared when Robert Boyle (1627-1691), a British physicist and chemist, concentrated on developing medicines and pills for the sick, beginning the traditions of the modern chemist.



An alchemist at work

Chemists today

Today there is a chemist's shop in almost every High Street in our towns and villages. They are run by *pharmaceutical* chemists, (the word pharmaceutical comes from a Greek word meaning drugs), who dispense medicines and pills prescribed by doctors to their patients. They no longer make many medicines as most are prepared on a big scale by large drug companies.

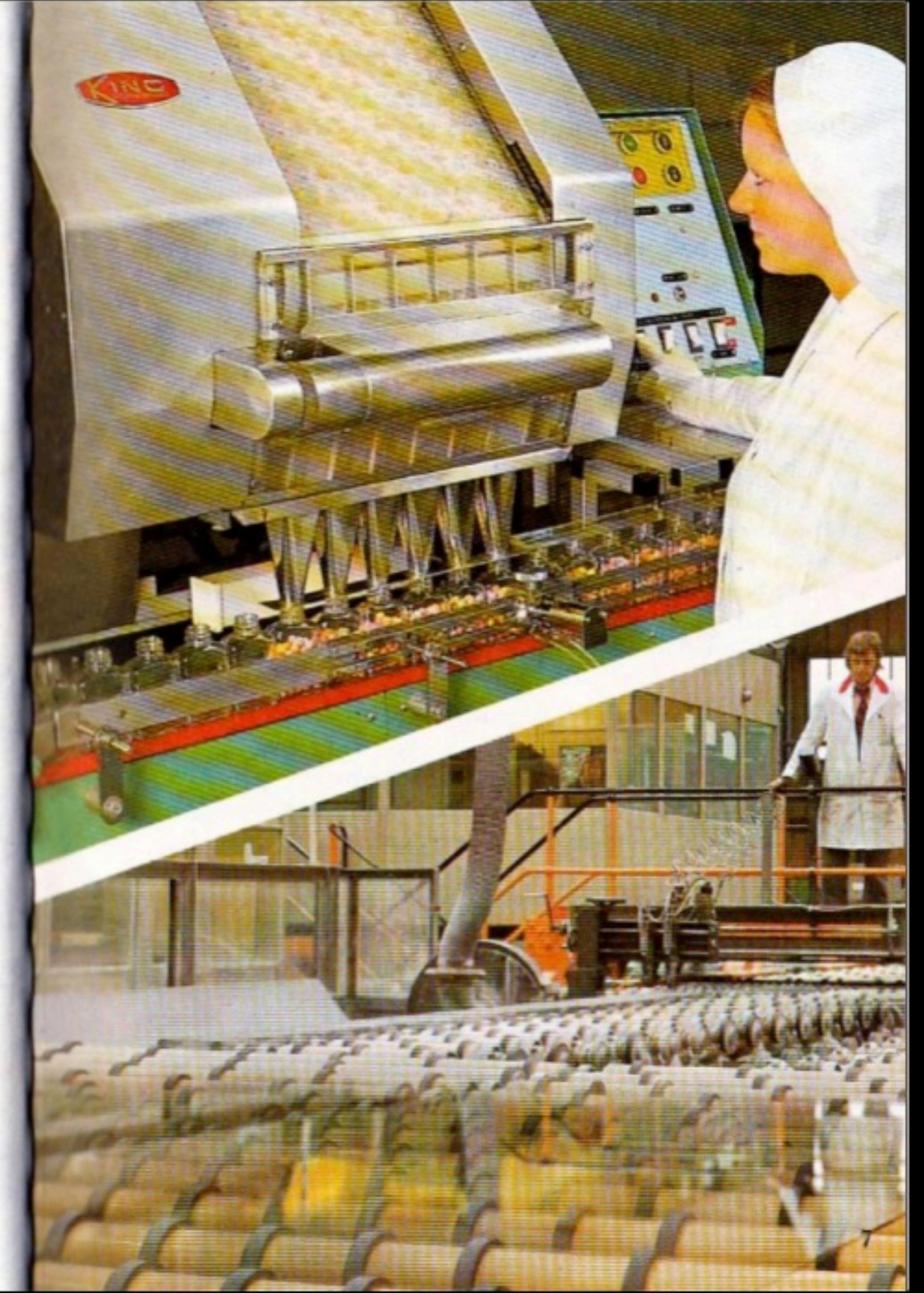
In industry there are chemists who spend their working time doing research. They have changed our daily lives by using natural and man-made materials to produce new medicines, agricultural materials and clothing fabrics. Working with doctors, farmers and industrialists, chemists help us to live healthier and more comfortable lives.

Every day we use many materials produced as a result of a *chemical change*. This means that a new substance is made through the action of one material on another. Steel is produced when iron ore is heated in huge furnaces; glass is created from sand that is heated until it melts. Other chemically produced substances are detergents, plastics and rubber.

In this book we are going to explore some household chemical substances. You don't need many special items for the experiments because you can probably find them in your kitchen at home.

PLEASE REMEMBER TO ALWAYS ASK A GROWN-UP FOR PERMISSION BEFORE TAKING THINGS FROM THE KITCHEN.

Chemists, like all scientists, always write notes about their experiments. You could keep a record of all your investigations. Remember to read the instructions and to follow them carefully.



top *Bottles being filled with multi vitamin pills*

bottom *A sheet of glass comes off a production line*

Equipment for your chemistry laboratory

Here is a list of some of the equipment you need for the experiments in this book. When you decide to try an experiment, collect all the things you need, cover a working top or table with newspaper, and place everything needed for the experiment in front of you. Don't get half way through an investigation and find that something is missing. You may ruin an experiment by going to search for something at a vital time.

Containers:
(Collect as many as you can. Wash and dry them, and keep them safe until you need them.)

old cups and saucers,
metal foil dishes,
liquid detergent containers,
clean yogurt pots,
milk bottle tops,
old saucepans, plastic bags,
heat-proof Pyrex jug,
small glass jars with lids (e.g., meat or fish paste jars),
egg cups,
jam jars of various sizes,
plastic bowl or bucket,
sieve, matchboxes

Some of the substances you will need:

sugar, salt, alum,
cream of tartar,
baking powder,
beetroot, red cabbage,
washing soda (sodium carbonate crystals),
vinegar, tea leaves,
coffee, earth,
soap powder or detergent,
garden lime,
sand, onion skins

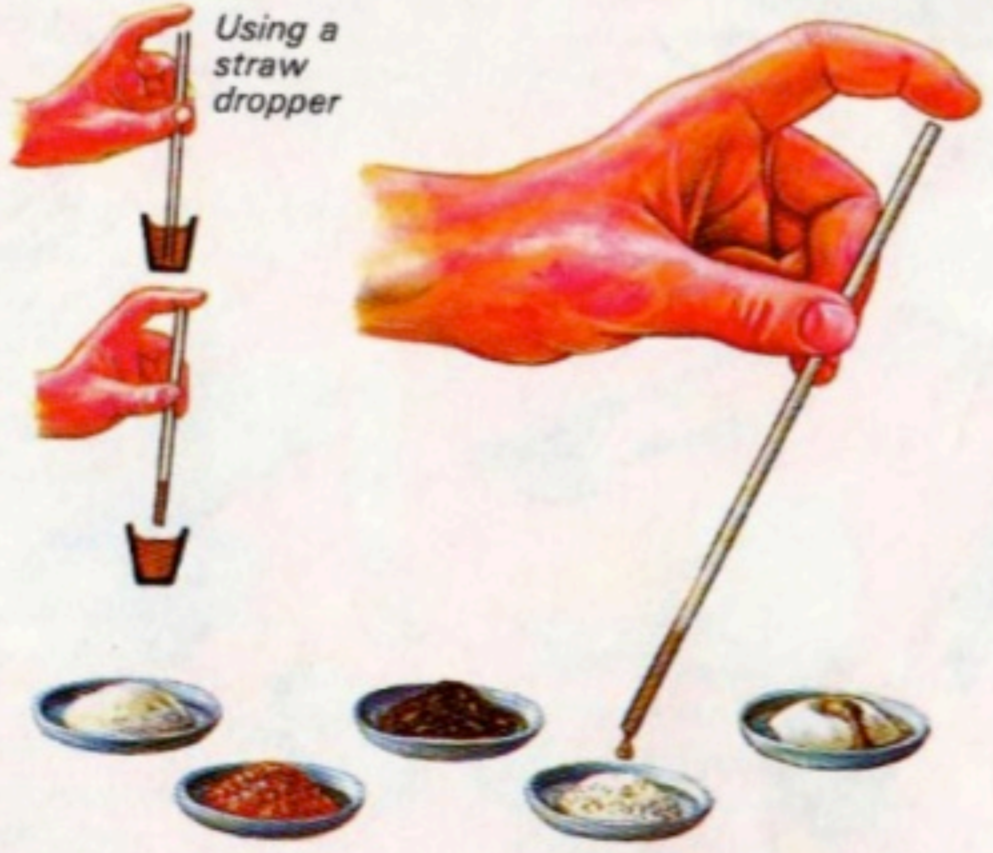
Other items:

magnifying glass,
cardboard,
matches, string,
nylon thread,
tablespoons,
teaspoons,
cotton wool,
paper, tissues,
notebook and pencil,
tapers or spills,
drinking straws,
scissors,
paper towels or kitchen roll

Testing things

Chemists study many different substances in their laboratories and find out what they can about them. When they are given an unknown substance, they first look at it closely to see if they can recognise it. If they can't, they experiment on the unidentified substance with other chemicals and watch what happens. These other chemicals are known as *testing agents*.

We can learn more about ordinary everyday substances in the same way. Our testing agent is vinegar, which is a weak acid (usually ethanoic acid). When an acid like vinegar comes into contact with certain substances, fizzy bubbles are produced. These bubbles are a gas called *carbon dioxide*. Let's find out how many substances in your kitchen produce carbon dioxide bubbles.



Release a few drops of vinegar onto each substance

Things you need for this experiment:
1 eggcupful vinegar
1 teaspoonful each of: starch, salt, sugar, baking powder, tea leaves, coffee, soap powder (or detergent)
1 Alka Seltzer tablet
10 clean, dry, milk bottle tops
drinking straw
drinking glass

What you do:

(1) Put the milk bottle tops in front of you and carefully place a small amount of each powder to be tested into separate milk bottle tops. Leave the Alka Seltzer tablet until later.

(2) Use the straw as a chemical dropper. Dip one end of the straw in vinegar and place one finger over the end as you take it up from the liquid. Drops of vinegar can be released by removing the finger at the top of the straw. Put one or two drops of vinegar onto each different substance in the milk bottle tops.

(3) Watch each one carefully and make a note of what happens. If the vinegar makes each substance fizz, carbon dioxide gas is being produced.

(4) Now put the Alka Seltzer tablet into a glass of water. What happens? You should see the tablet sink to the bottom and produce a stream of carbon dioxide bubbles. In scientific terms, even cold water is warm, compared to ice for example. If you hold the bottom of the glass, you will feel the cold water get colder. The reaction of the tablet and the production of carbon dioxide takes heat from the water, cooling the liquid down.

The moving moth balls experiment

Things you will need:

a large jam jar
moth balls (obtainable from a chemist or hardware store)
water
tablespoon
baking soda
vinegar

What you do:

(1) Pour some cold water in the jar until it is about three-quarters full and add a tablespoonful of baking soda and a tablespoonful of vinegar.

(2) Stir the mixture well until all the baking soda has disappeared. Let this mixture settle.

(3) Put some moth balls into the solution.

(4) They sink to the bottom but after several minutes you will see bubbles of carbon dioxide form around them and the moth balls will rise to the surface. The bubbles burst as they come into contact with the air, and the moth balls sink to the bottom of the jar. More carbon dioxide bubbles form and the moth balls rise again.

Carbon dioxide bubbles are formed and the mothballs rise to the surface

What is carbon dioxide?

Carbon dioxide is an invisible gas present in the air. When we breathe out, carbon dioxide comes out from our lungs. If we separate carbon dioxide from all other gases in our atmosphere, we find that it amounts to about one part for every three and a half thousand parts of air.

You can see the effect of the carbon dioxide gas we breathe out in the following experiment. You need a teaspoonful of garden lime such as gardeners use in the winter months to condition garden soil. (*Be sure to wash your hands after using lime because it can irritate the skin.*)

What you do:

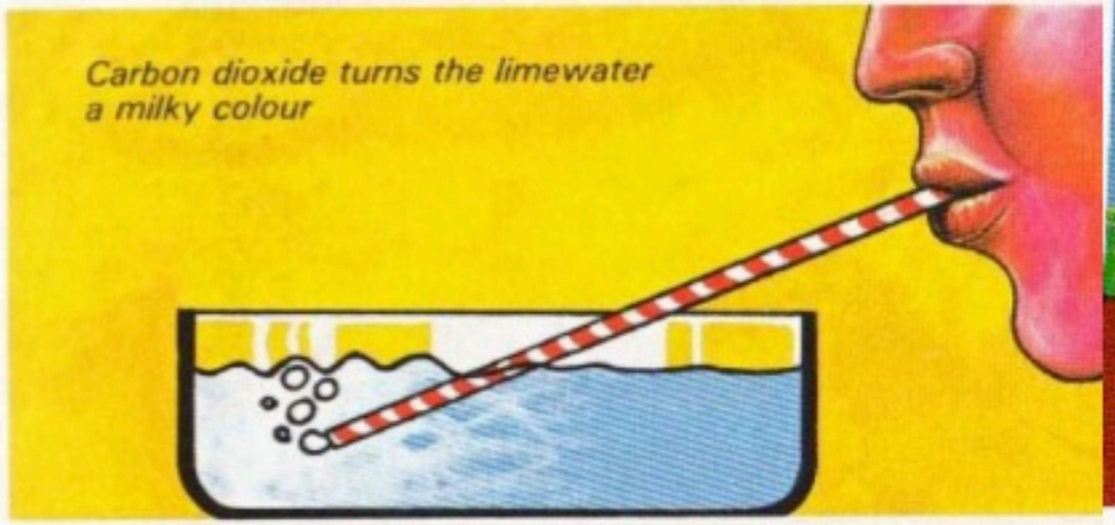
(1) Put the lime into a jar and half fill with tap water.

(2) Stir it well and let it stand until it has settled.

(3) Pour off the liquid into another jar, leaving the lime sediment at the bottom. You can throw this away as it isn't needed anymore.

(4) Blow gently into the liquid through a straw.

What happens? The liquid turns cloudy because the carbon dioxide gas in your breath joins with the lime water to make a substance called *calcium carbonate*, which turns the water a milky colour.



Carbon dioxide turns the limewater a milky colour

Carbon dioxide is an important gas needed by green plants and trees for making food in their leaves. Green leaves are like little factories and use carbon dioxide to make sugar. All natural water has carbon dioxide in it, too, which keeps water plants alive. Animal life is dependent on green plants for survival, so without carbon dioxide gas, life as we know it would perish.

When carbon or anything containing carbon is burned in a good supply of air, carbon dioxide is formed. The coal and oil we burn in factories and our homes makes hundreds of cubic metres of carbon dioxide, which joins the air when it is discharged through tall chimneys.

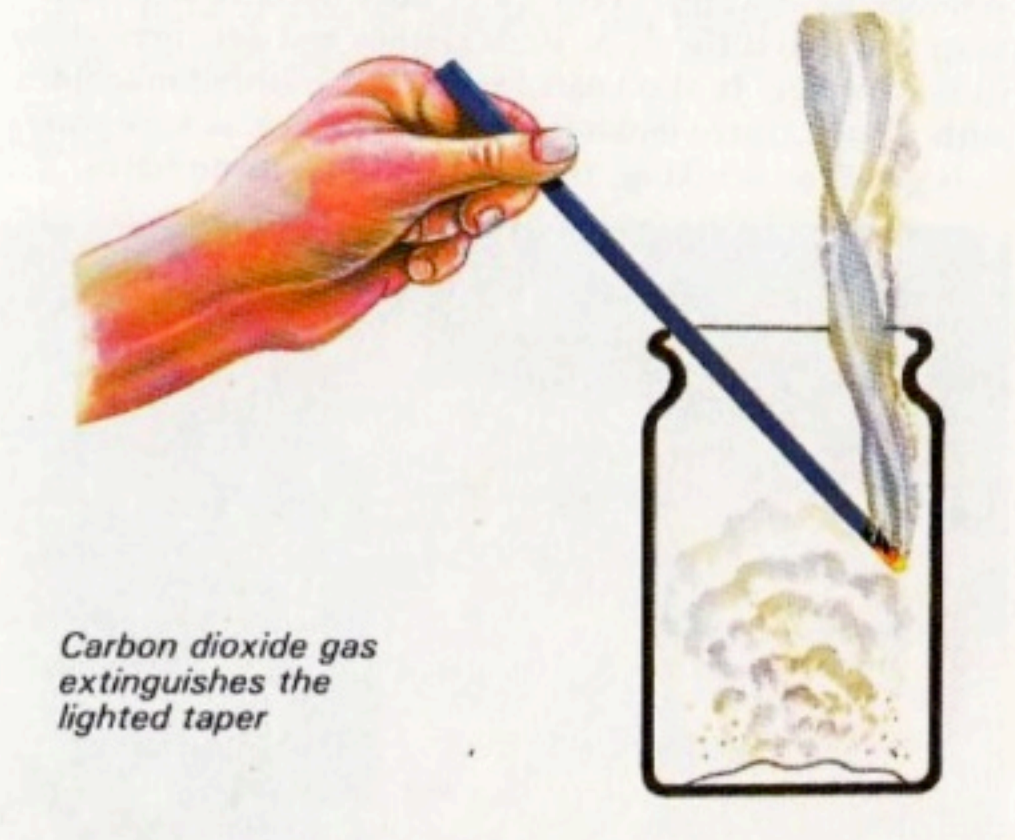
Carbon dioxide gas is heavier than air, and will sink to the bottom of any container you make it in. Scientists have worked out that it is 1.5 times heavier than air.

Pour a little vinegar into a plastic bag and add some baking soda to make carbon dioxide. Squeeze the mouth of the bag tightly shut. What happens?

All living things help each other to live by exchanging oxygen, carbon dioxide, water and organic waste

Try this experiment.

Put a teaspoonful of baking soda in a dry jam jar and pour in about ten drops of vinegar. When the baking soda is bubbling and giving off carbon dioxide, carefully put a lighted taper into the bubbling pot. What happens?



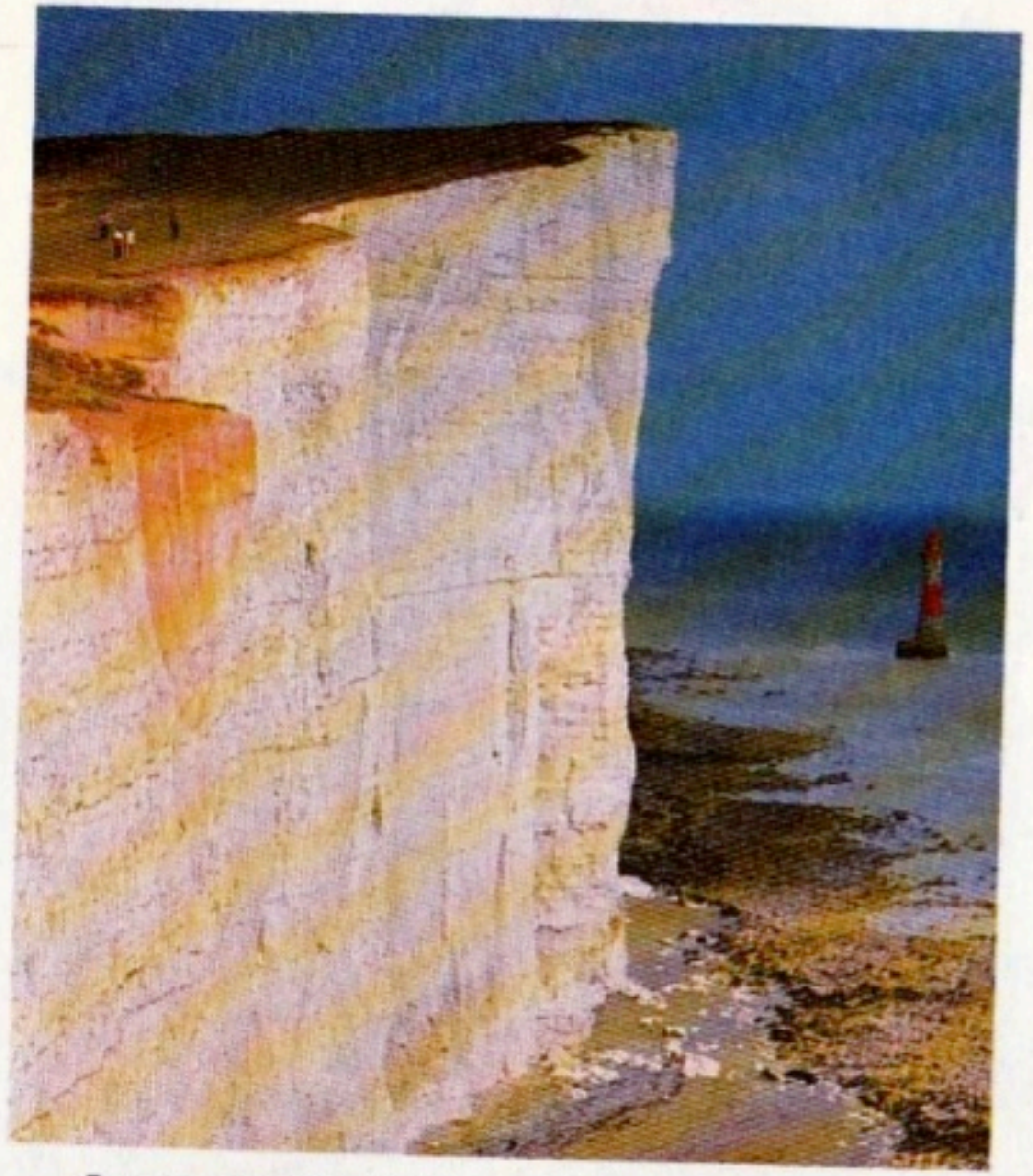
Carbon dioxide gas extinguishes the lighted taper

The flame goes out because of the carbon dioxide coming from the fizzing baking soda. Carbon dioxide gas puts out flames. Some fire extinguishers operate by forcing jets of carbon dioxide foam through a nozzle onto flames.

Lemonade contains a solution of carbon dioxide in water, but since it is dissolved under pressure, much of it escapes when the lemonade bottle top is unscrewed. Pour some lemonade into a glass and look carefully through a magnifying glass at where the bubbles form. Do they form just anywhere? Do they appear as large bubbles? What happens if you tap the glass with a pencil?

Hard water

As rain water falls through the air it collects and dissolves a little carbon dioxide. When the rain hits the ground, it trickles into the soil, and if there is any limestone or chalk in the earth, it joins with the water to produce hard water. Hard water does not mix well with soap and it is difficult to wash clothes and get them clean in hard water. It also coats kettles and washing machines with a hard, furry-looking substance known as *lime scale*. It is good for drinking, though, and does us no harm.



Beachy Head shows the vast layer of chalk which lies beneath the earth in some parts of the country

Many homes have water softeners which work in a simple way. The house water flows through a vessel containing a coarse powder called Zeolite. This, together with salt, acts as a water softener.

Is your house water hard or soft? Look inside your kettle. If there is a lot of lime scale you are probably living in a hard water area.

Dissolving

Many people sweeten tea and coffee by adding a spoonful of sugar. When the drink is stirred, the sugar disappears. We say it has *dissolved* in the hot liquid.

It is important for chemists to find out whether substances will or will not dissolve in water. They find this a helpful way of identifying unknown substances because some chemicals dissolve easily, others not at all.

Find out which kitchen substances dissolve in water.

Things you need:

¼ teaspoonful each of sugar, curry powder, table salt, baking soda and chalk
(crush a stick of chalk until it is a fine powder)
5 small, empty jars with lids

What you do:

(1) After labelling the jars 1 to 5, half fill each one with water.

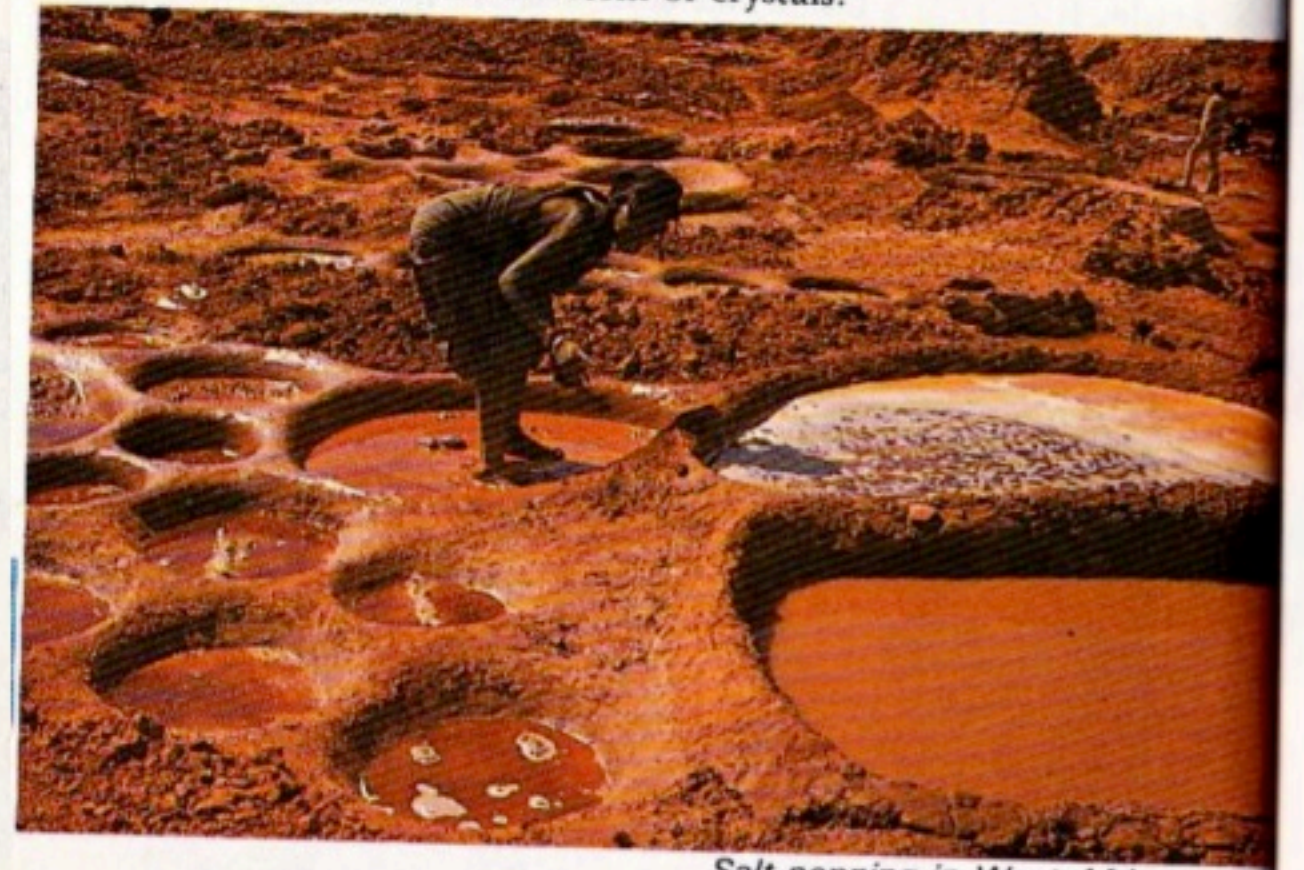
(2) Add a different substance to each jar. Put on the lids and shake each jar twenty times.

(3) Take off the lids and see which powders have dissolved. (You can keep the jar with table salt in it for the next experiment.)

When a substance dissolves in liquid we say it is *soluble*. When it does not dissolve it is *insoluble*. Is sand soluble in water? Try some experiments of your own and keep a record of soluble and insoluble substances.

Evaporation

Take the jar in which you dissolved table salt and drain off 2 teaspoonfuls of the liquid onto a clean saucer. Leave the saucer in a warm place, such as a windowsill, for a few days. The water will eventually evaporate leaving behind the salt in the form of crystals.



Salt panning in West Africa

Solutions

Sea-water covers about two-thirds of our planet and is a good example of a *solution* because there are many salts dissolved in it. A solution is the blending of two or more substances. If you put a small amount of salt into a cup of water, you get a weak or *dilute* solution. Add more salt and the solution gets stronger or more *concentrated*, as chemists say. The salt is called the *solute*, the water is the *solvent*. Sea-water is a concentrated solution because rain, through countless years, has been collecting salt from underground rocks and depositing it into the sea.

Find out how to make a solution of salt.

Things you will need:

salt	spoon
cup	magnifying glass
water	drinking glass

What you do:

(1) Drop a *pinch* of salt into ⅓ cup of warm water and stir it in. You now have a dilute salt solution.

(2) Add a *spoonful* of salt and stir, and the solution is now a concentrated one.

(3) Pour some of the concentrated salt solution into a drinking glass and hold it up to the light. Can you see any particles of salt floating in the water? Try looking through a magnifying glass for floating particles.

There are rules that solutions always obey

(1) The solute cannot be seen, even with a magnifying glass.

(2) Solutions cannot be filtered, because the particles are very small.

(3) They are always transparent.

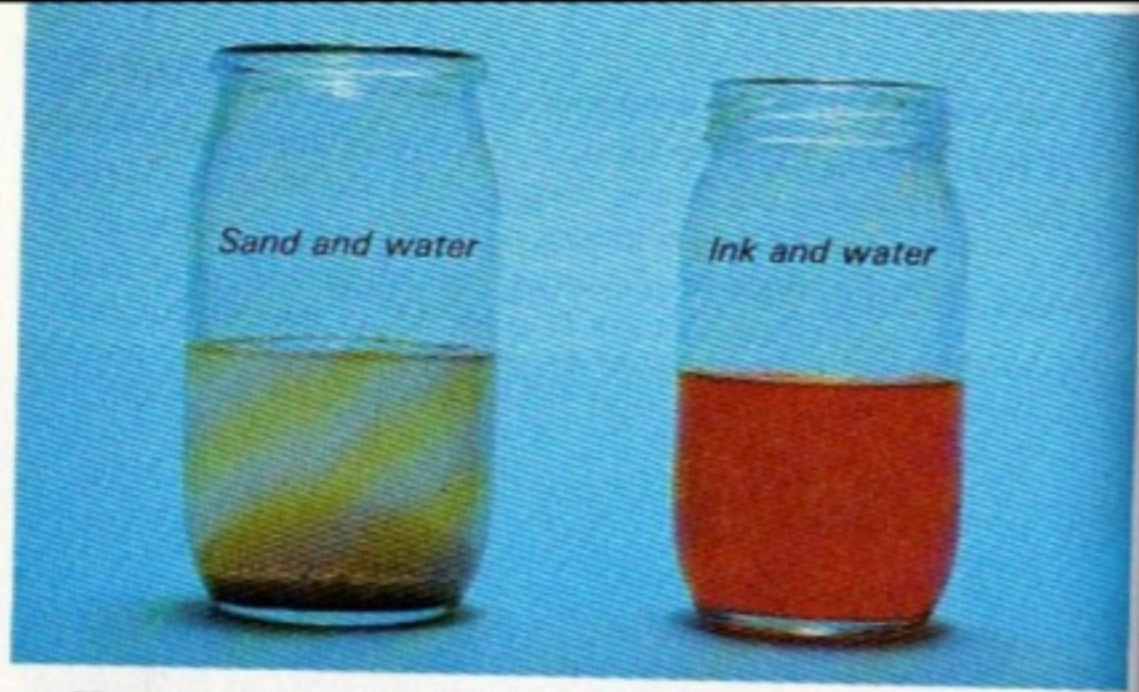
(4) The solute never falls to the bottom of the glass.

Mixtures

Not every substance will dissolve or follow the rules for a solution. When particles do not dissolve this is called a *mixture*. Which of the following are mixtures and which are solutions?

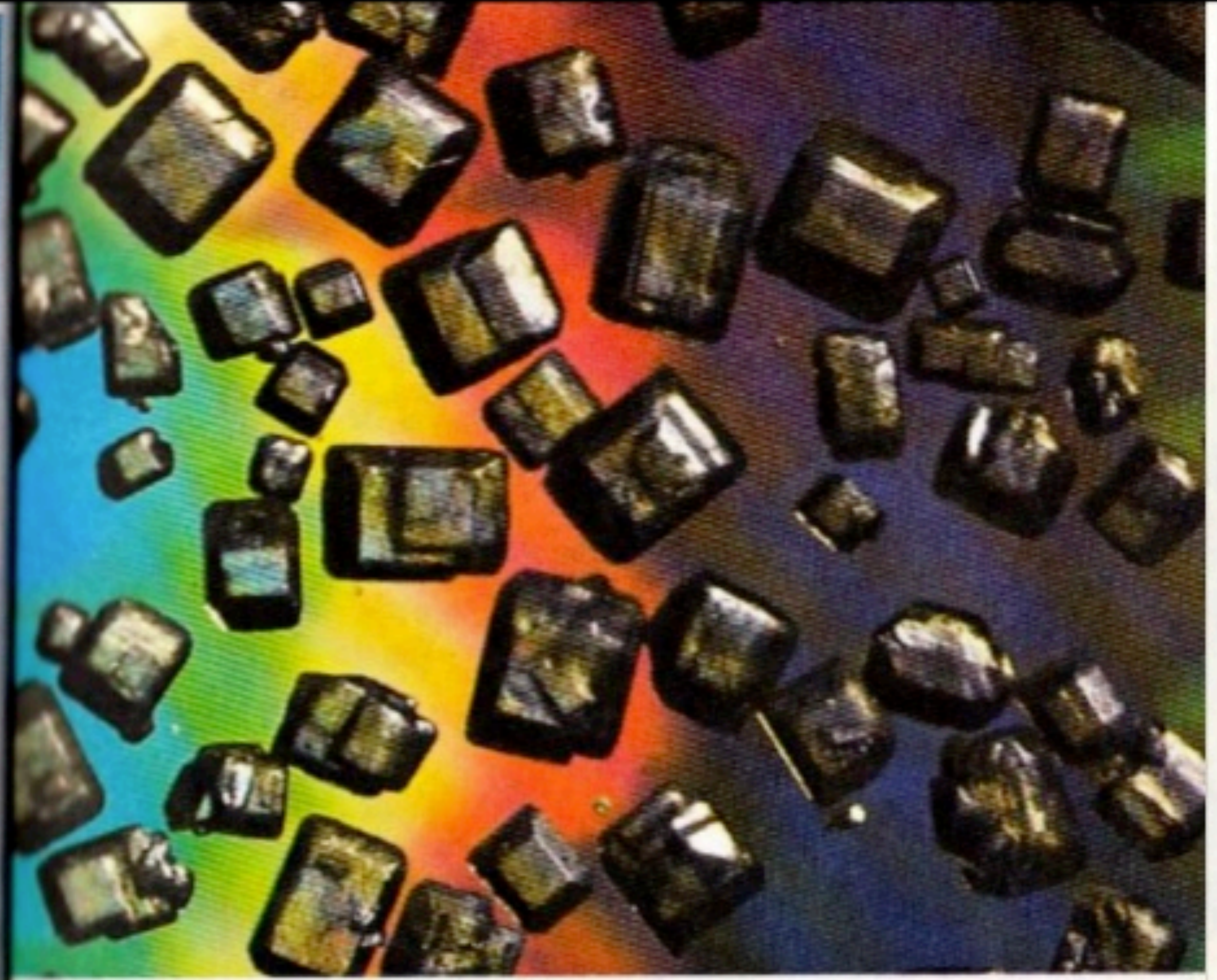
sugar and water	*ink and water*
sand and water	*pepper and water*

Add each substance to be tested to a jar of cold water and stir. Does the sand disappear? Can you see it with a magnifying glass. Is it a solution? List the solutions and mixtures in your notebook. Can you discover more mixtures and solutions?



Unsaturated, saturated and supersaturated solutions

If we squeeze a sponge under water, then release the pressure, the sponge fills with water. Lift the sponge out and water drips from it. The sponge is *saturated*. Chemists use this word in a similar way when they talk about solutions they work with in their laboratories.



Sugar crystals

A tablespoonful of sugar in a glass of cold water is called a *dilute* or *unsaturated* solution of sugar. If you keep on adding sugar until no more will dissolve, you would have a saturated solution. This means that the water is holding, *in solution*, as much as it can. If an extra pinch of sugar is added, some falls to the bottom.

A solution that contains more sugar than can normally be dissolved is called a *supersaturated* solution. Gently heat a cupful of water in a saucepan (take care!) Pour it into another saucepan and saturate it with sugar. Because the temperature of the water is high, the water will dissolve more sugar than it normally would.

Let the solution cool and then add another pinch of sugar. The extra sugar will act as *seed crystals* and the dissolved sugar will grow around it.

Desert chemistry

In a desert in Arizona, USA, there is a famous National Park called the *Petrified Forest*. Here there are great logs of beautiful minerals called jasper and agate.

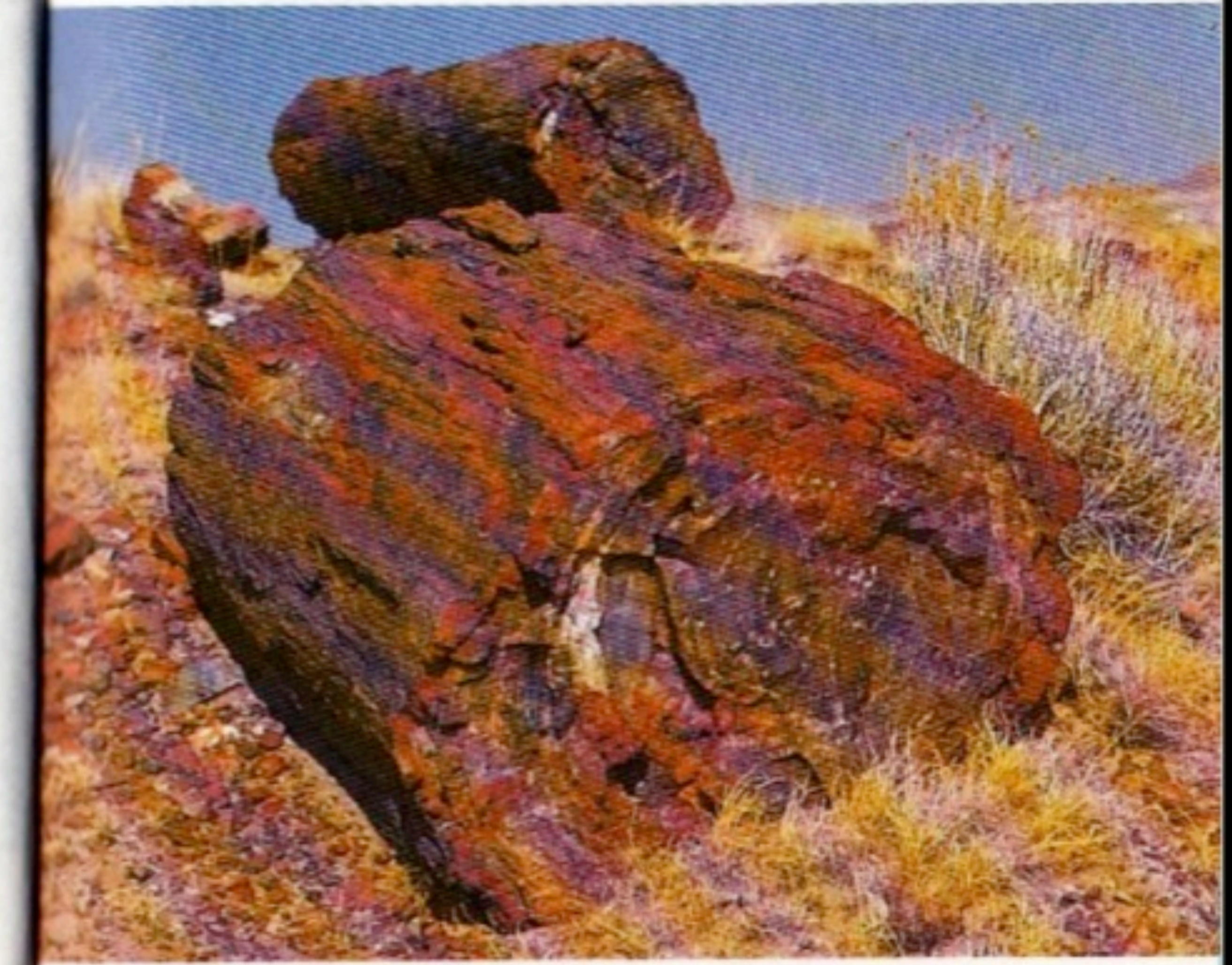
Petrified wood is manufactured by nature in a special way. The mineralised logs were once living trees in a prehistoric forest. When they fell to the ground, they were covered, before they could decay, by sand, mud and volcanic ash. Eventually a geological upheaval lifted the land, and millions of years of wind and rain exposed the trees. But they had changed – the wood had been replaced by coloured minerals. The trees are now solid rock.

Crystals in nature

Nature is perhaps the best chemist, and certainly grows the most beautiful and spectacular crystals. Minerals in the ground form crystals when conditions are right. There are many different crystal shapes and colours, some so delicate and perfect that they seem to have been made by expert craftsmen.

The word *crystal* comes from the Greek, *krystallos*, which means icy cold. It was once thought that crystals were water, frozen so hard that it would never melt. Some countries are famous for certain types of crystal, such as Brazil for its magnificent amethysts and South Africa for diamonds.

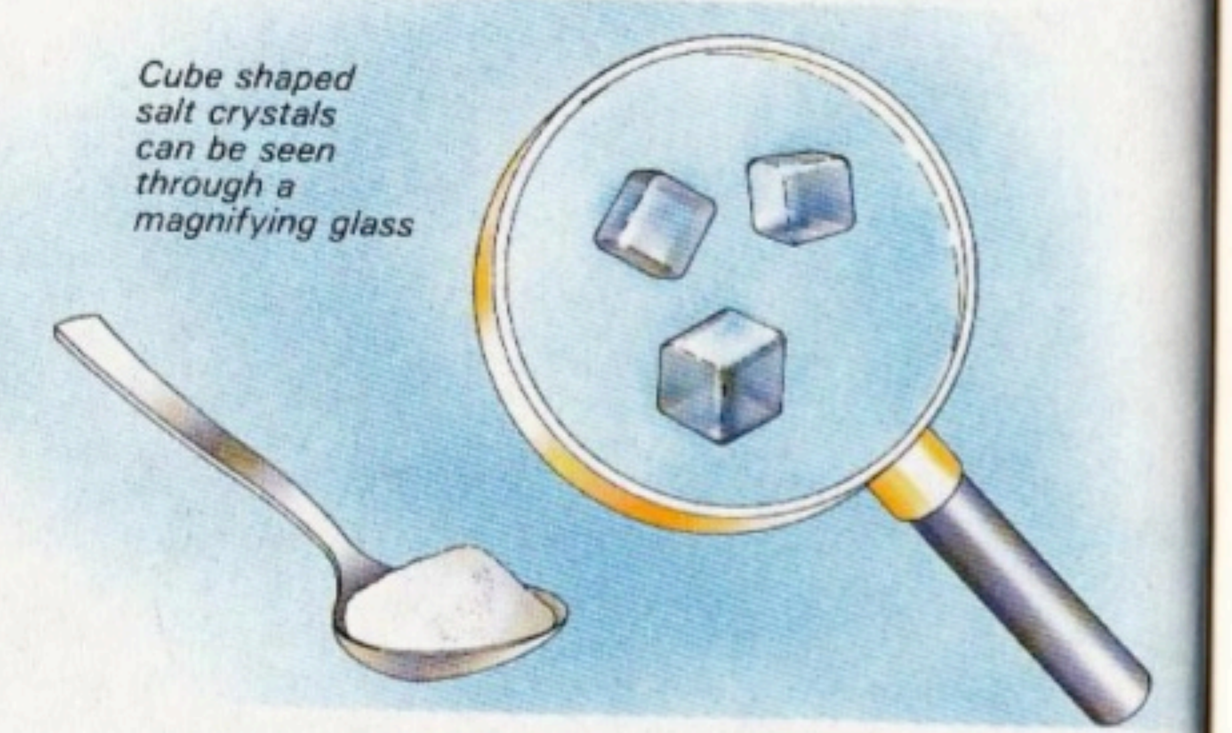
The best crystals are formed in rock cavities. Water movement on and in the earth's crust mixes minerals together in the ground. The fierce heat at the earth's centre forces molten rock towards the surface. The minerals in the molten rock are left behind when evaporation takes place, and crystals develop. The slower the evaporation of the water, the larger the crystals will be. This process is happening all the time.



above *A petrified log in the National Park, Arizona, USA*
below *Some of the earth's natural crystals*

Growing crystals

Before you try growing crystals of your own, look at some sugar and table salt through a magnifying glass. What do you notice about the shape of their crystals?



You can grow crystals at home, using the same method as occurs in nature. Growing crystals will give you hours of pleasure and delight. You need patience, though, because crystals grow slowly. The longer you wait the better the result.

Things you need:
4 clean jam jars
14 g table salt
14 g sugar
14 g cream of tartar } Obtainable from a chemist
14 g alum
nylon thread
water
old saucepan
old saucers

What you do:

The following recipe can be used for all the substances in the list but it is a good idea to grow *alum* crystals first because they grow fastest.

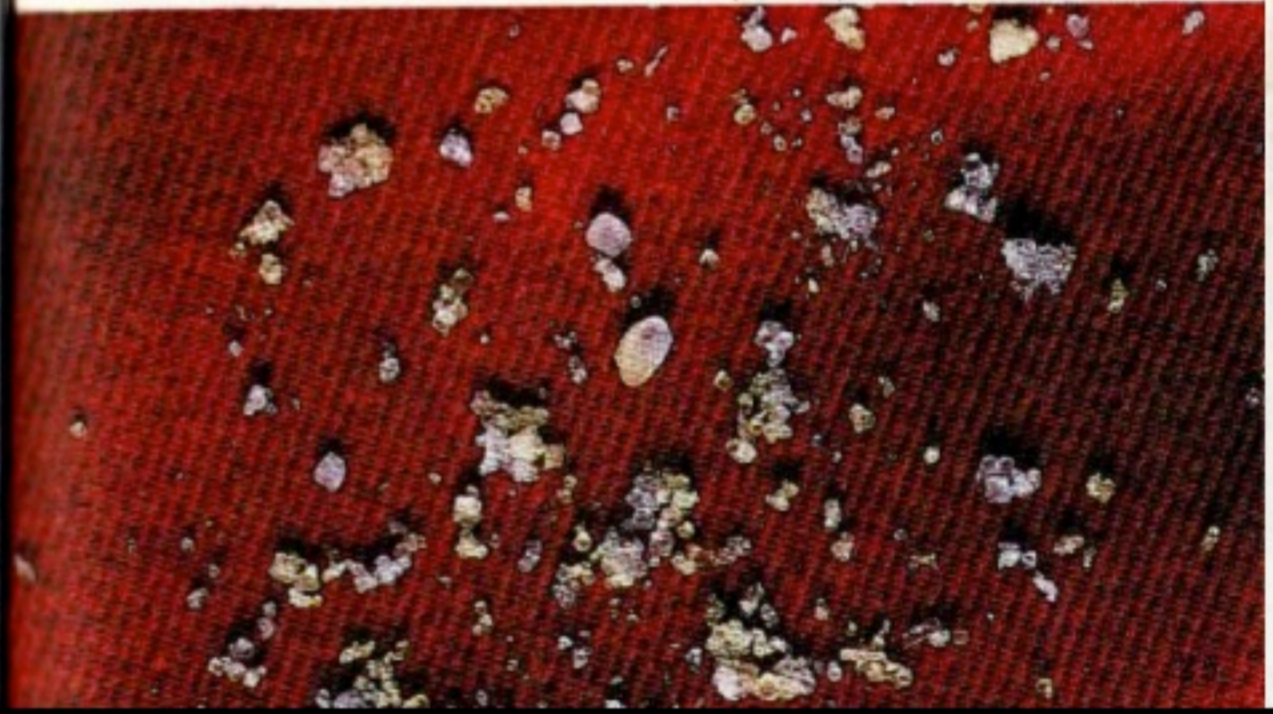
(1) Make four tops for the jam jars. Turn one jar upside down on a sheet of cardboard, carefully draw a circle round the mouth, and then cut out the circular disc. The disc you have made will fit over the top of the jar without falling in. Repeat this for the other jars. Pierce two small holes in each disc.

(2) Gently heat 75 ml of water in the old saucepan and add 14 g of alum. Stir until all the alum has disappeared.

(3) Take the pan off the heat and let the solution cool down. Pour a little onto a saucer and save the rest of the solution in one of the jam jars. Wash out your saucepan.

(4) Drop a single alum crystal into the saucer and leave it on a windowsill overnight. The next day there will be clusters of tiny alum crystals in the bottom of the saucer. Look at them with a magnifying glass. What shape are they?

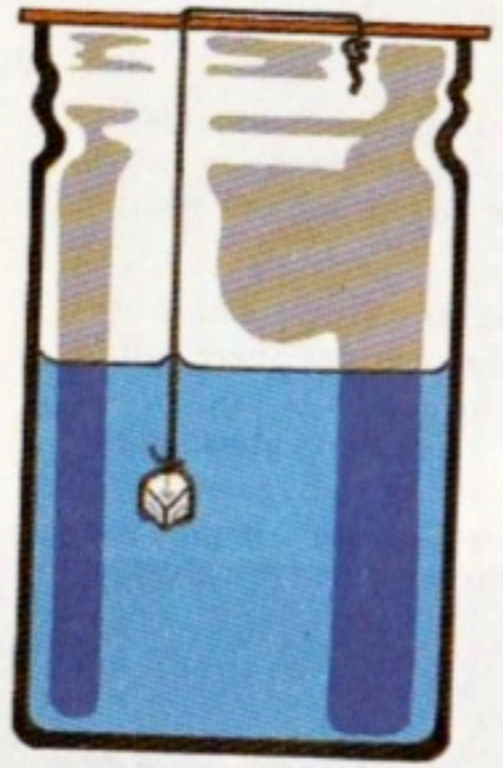
Alum crystals produced by evaporation



(5) Choose the biggest and best shaped crystal. Tie a length of nylon thread to it. This seed crystal is going to form the base for new crystal growth in the jam jars.

(6) Pour the solution you saved in the jam jar back into the saucepan and gently heat this again until any crystals have dissolved (some crystals will have formed in the jar overnight).

(7) Let this cool again. Pour it back into your jar and wash out the saucepan.



(8) Tie the seed crystal to the cardboard disc and hang it so that the crystal is suspended in the solution (see diagram). Leave it somewhere cool and safe for a few days.

(9) The suspended crystal will grow into a bigger, more beautiful alum crystal. If you want to increase its size, then make another solution and repeat the experiment.

A crystal garden

The salts of most metals combine with a substance called sodium silicate. Sodium silicate dissolves in water to form a solution known as water glass. It is used to preserve eggs and you can buy it from a chemist's shop.

DANGER: You can grow the most beautiful crystal garden but you will need to buy substances from the chemist *which should NEVER be put in your mouth. ALWAYS* wash your hands after touching these crystals. Follow these instructions carefully.

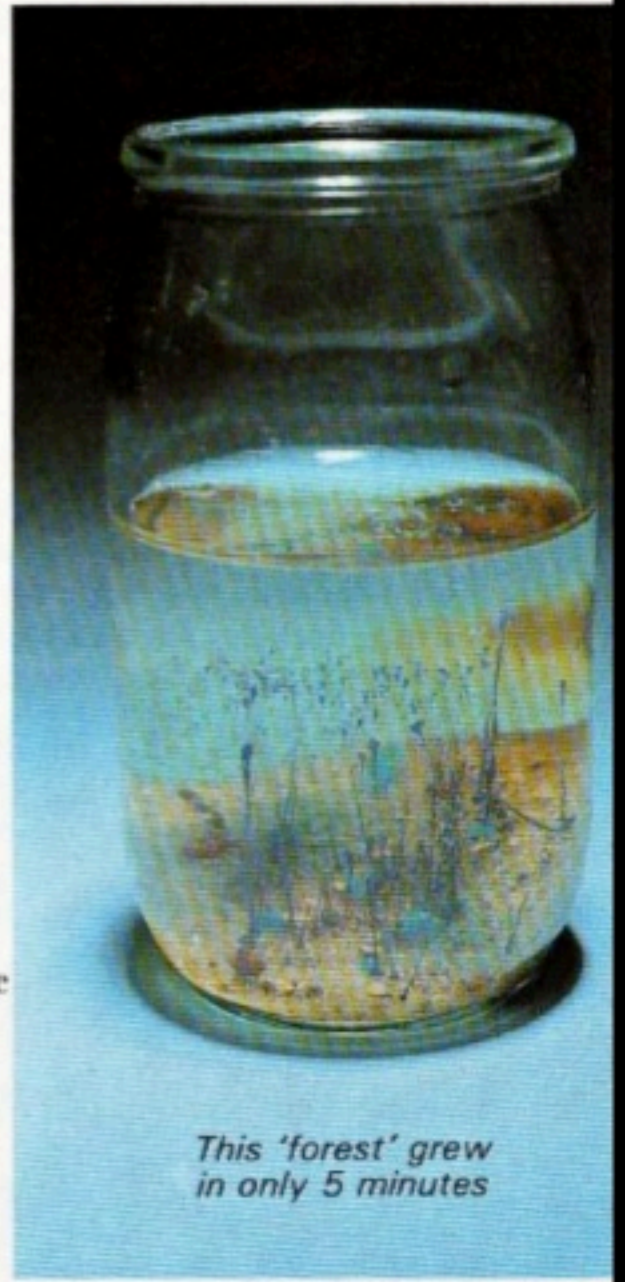
To make a crystal garden you need:
water glass
(or egg preserver)
a large jam jar
some crystals of ferrous sulphate, copper sulphate and iron alum (you can buy these from the chemist in small quantities, but they must not be put into your mouth)
washed sand

What you do:

(1) Half fill the jar with water glass and fill it to the top with cold tap water.

(2) Put in a layer of washed sand about 1 cm thick at the bottom of the jar, and drop in the crystals one at a time.

(3) They will begin to produce lots of tiny crystals that grow towards the surface of the water, forming a beautiful crystal garden of different coloured crystals. Be patient for the best results!



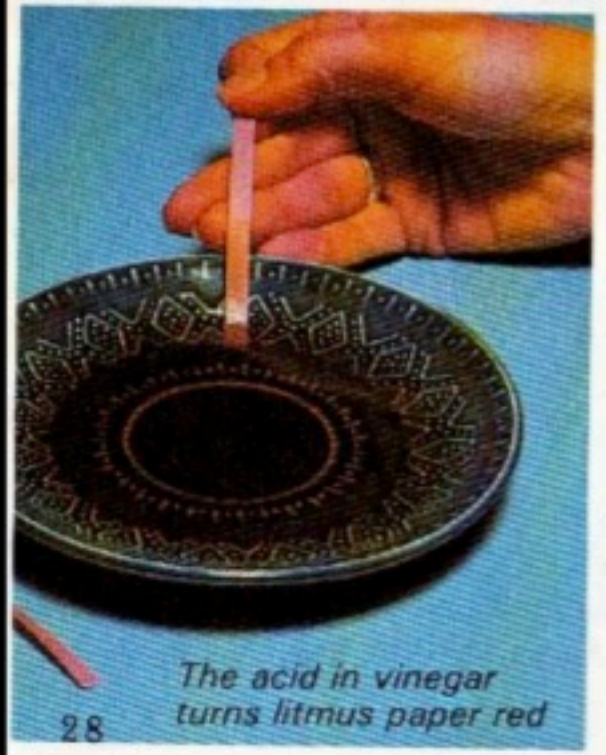
This 'forest' grew in only 5 minutes

Acids and alkalis

Acids and alkalis are important chemical substances. All acids taste sour. The word *acid* comes from the Latin, *acidus*, which means sour. Hundreds of acids occur in the natural world, even in our gardens. Unripe fruits taste sour because they contain acid. For instance, unripe apples contain *malic acid* and grapes contain *tartaric acid*. Lemons contain *citric acid* which is why fruits such as lemons and limes are called citrus fruits.

Most acids are harmless but some are very dangerous. Sulphuric acid, hydrochloric acid and nitric acid are all very harmful and, if touched, will destroy your skin. All three, though, are used by chemists in the manufacture of fertilisers and plastics.

The word *alkali* is Arabic and means *ashes*. Alkalis are made from burning wood and some kinds of seashore plants. They have a bitter taste and feel soapy when rubbed between your fingers. Vast areas of desert in the USA are alkaline regions where few plants grow and little animal life can survive. Sodium hydroxide, also known as caustic soda, is a well known but very dangerous alkali. It destroys human skin and clothing very quickly.



The acid in vinegar turns litmus paper red

Chemists use a specially treated paper called *litmus paper* when they test unknown liquids to check if they are acids or alkalis. Litmus is a dye made from plants. It is *neutral*, which means it contains neither acid or alkali. When it is dipped into *acids* it turns *red*, and it turns *blue* when in contact with *alkalis*. Chemists call litmus paper an *indicator*. You can make an indicator to identify acids and alkalis in your kitchen.

Things you need:
half a fresh red cabbage, coffee, water, orange squash, toothpaste, earth, vinegar, tea, scouring powder (e.g., Vim or Ajax), two plastic bowls, old saucers

What you do:

(1) Cut the red cabbage into thin strips and put these into a bowl.

(2) Boil a kettle and very carefully pour some hot water into the bowl. The juice from the cabbage will colour the water a darkish purple. Let the solution cool and strain the liquid into a plastic bowl. Throw away the cabbage.

(3) Make a solution or mixture of each of the substances in the list and pour some of each one into a different saucer.

(4) Using a straw as a dropper, drip a couple of drops of cabbage water onto each solution in turn. What happens? Which substances are acid?

The saliva in your mouth may be acid or alkali. Test it and see and then test the saliva of other members of your family to see any differences.

Dyes

Picking blackberries is a messy job. Your fingers get stained with blackberry juice. Early man discovered how to change the colour of his clothes with berry juice, and gradually developed the art of *dyeing*.

Nowadays chemists make dyes for us, but until the middle of the 19th century, all dyes were made from plants, animals, and minerals found in the ground. A long time ago, the Phoenicians crushed and boiled murex sea shells to make purple dye. The word *Phoenician* comes from a Greek word for purple. Their *Tyrian* purple was special because it took 8,500 shells to make one gram of dye! Roman Emperors wore Tyrian purple as a sign of high rank.

Part of an old manuscript known as the Book of Kells

Black dye was made from oak galls. The gall is not a tree fruit. It develops when gall wasps lay their eggs on oak trees. The larvae wriggle inside the branches and develop the woody galls. By boiling galls in water, monks extracted a strong, black dye which they used as ink for writing their manuscripts.

A Roman Emperor in Tyrian purple

Dyes were very important in the textile industries in Yorkshire and Lancashire during the Industrial Revolution in the late 18th century. Certain areas became associated with particular colours. Green baize and red flannel from Manchester and Huddersfield were exported to America. The Navajo Indians in America were expert weavers but could not make a good red dye, so they used Yorkshire red flannel and rewove it into rugs and blankets.

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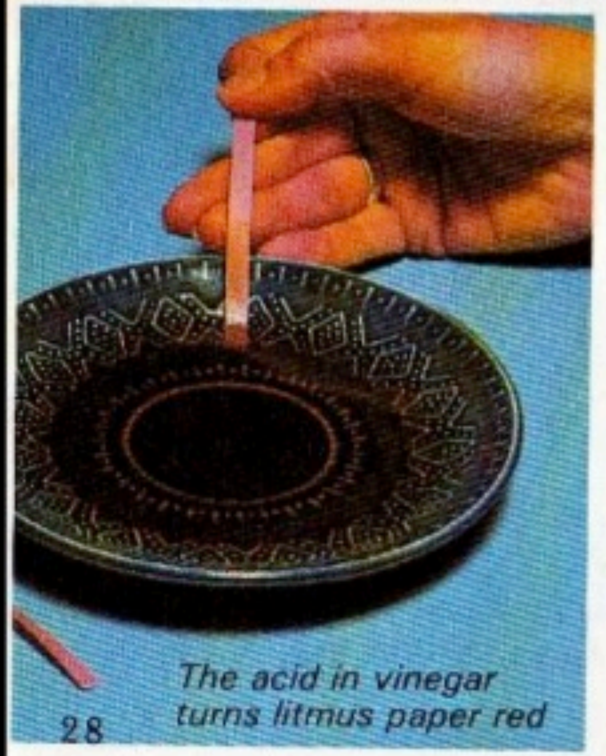
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Mordants

Some natural and man-made dyes do not give good permanent colours unless another chemical is used when the cloth is boiled. These chemicals are called *mordants* and they make the dye *bite* into the cloth. Urine, tree bark and wood ash have been used as mordants to produce lasting colours, but today, we can buy man-made mordants from chemist shops.

Dyes and dyeing

Dyeing takes patience, care and time; set aside an afternoon and a morning for this chemistry experiment.

Things you need:

water	white handkerchief or piece of white cotton cloth
60 g alum	2 large saucepans (enamel or stainless steel)
1 tablespoonful cream of tartar	jam jar
30 g onion skins	cloth
sieve	

What you do:

(1) Dissolve the alum and cream of tartar in 500 ml of warm water in the jar and add this mixture to a large pan of cold water.

(2) Put the handkerchief or cloth into the pan and gradually heat, stirring all the time. This will mordant the material.

(3) Simmer gently for an hour and then switch off the heat and allow the water to cool.

(4) Spread the onion skins on to a chopping board and cut them into very small pieces. Put them into a small container full of water and soak them overnight.

(5) On the second day, boil the onion skins and simmer for an hour. Then strain the liquid into another large pan, leaving the skins behind in the sieve.

This piece of cloth was dyed in the onion skin liquid

(6) Add enough warm water to the liquid in the pan to cover the handkerchief or cloth.

(7) Add the mordanted cloth and bring to the boil. Simmer gently for one hour. Take the pan off the heat and leave to cool slightly.

(8) Carefully remove the cloth from the pan, using a pair of tongs, and wash it in soapy water. Rinse the handkerchief or cloth until the water runs clear.

What colour have you dyed your cloth? Now experiment with other substances. Dyes can be made in this way from many things, including tea leaves, pine cones and red cabbage. See what colours you produce and make notes of quantities in your notebook each time you make a new colour.

Cold-water dyes are easy to make, but they will not stay in cloth. It's fun to make some, though, from such things as earth, coal dust, or anything that stains, and to use them as paints for your next water-colour picture.

Paper and paint

Chemistry helps in the production of paper and paint. It is thought that paper was first used by the Chinese, and the idea soon spread to other parts of the world. In 1490, the first paper mill in England was opened in Stevenage, a town in Hertfordshire.

Wet end of a paper machine showing pulp

If you rip a sheet of paper and look closely with a magnifying glass at the torn edges, you can see fine hair-like fibres of *cellulose*, the substance from which the cell-walls of plants and trees are made. When paper is

Reel-up on a paper machine

produced, wood is broken down until every fibre is separated and the *pulp* is then mixed with water.

Paper was made by hand until early in the 19th century. Most paper today is made in huge paper-making machines, from wood pulp or other vegetable fibre. The pulp is boiled in chemicals and then bleached (if it is going to be white), dried and cut into sheets.

Paint making began when Stone Age man used 'earth colours' to make his cave paintings. Today, chemists use natural and man-made substances to produce paint. One recent development discovered by chemists is latex emulsion paint which contains man-made rubber. This paint is very easy to use and is long-lasting: ideal for the home decorator.

Making nettle paper

You can make paper from common stinging nettles.

Things you need:

lots of nettle leaves	old large saucepan
pair of big scissors	plastic bucket
sieve	pair of gardening gloves
newspapers	

What you do:

(1) Put on the pair of gardening gloves and strip about 50 leaves off some stinging nettle plants.

(2) Cut them into small pieces and soak them in a bucket of cold water for two or three days.

(3) Drain off the water and tip the leaves into a saucepan, half full of water. Boil the cut leaves until the water turns a straw colour.

(4) Let the water cool and drain the leaves into a sink.

(5) Scoop out the leaves with the sieve and spread them out carefully.

(6) The fibres of the nettle leaves bind together, leaving a sheet of thick, yellowy 'paper'.

(7) Rest the damp paper between sheets of newspaper and press with two or three heavy books. Remove your hand-made sheet of paper after two days.

Separating colours

As well as producing new colours for the clothing industry, chemists also investigate coloured liquids. Colours are not always pure. They are often several colours mixed together. Have you noticed that if a page of your writing gets wet, the ink or felt pen colour runs and spreads across the page, separating into different colours?

Let's find out how to separate colours.

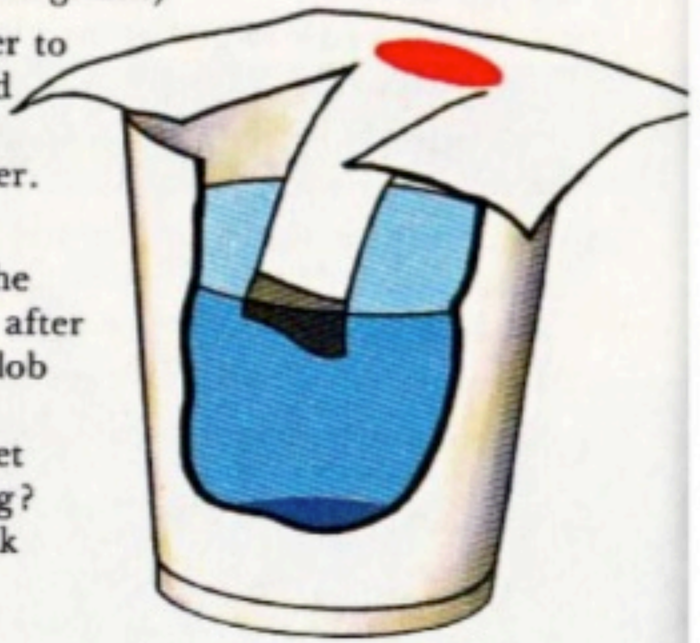
Things you need:

several yogurt pots	drinking straws
felt-tipped pens	food colouring
kitchen roll or blotting paper	

What you do:

(1) Cut several strips of kitchen roll about 10 cm by 10 cm and cut a narrow strip down to the centre of each one. Bend the strip back and put it into a pot half full of water. (See diagram.)

(2) Use a straw dropper to drop a blob of food colouring onto the centre of each paper. What happens?



The water rises up the strip to the colour and after a while separates the blob into different colours. What colours do you get from red food colouring? Can you split up the ink colours of felt pens?

Filtering liquids

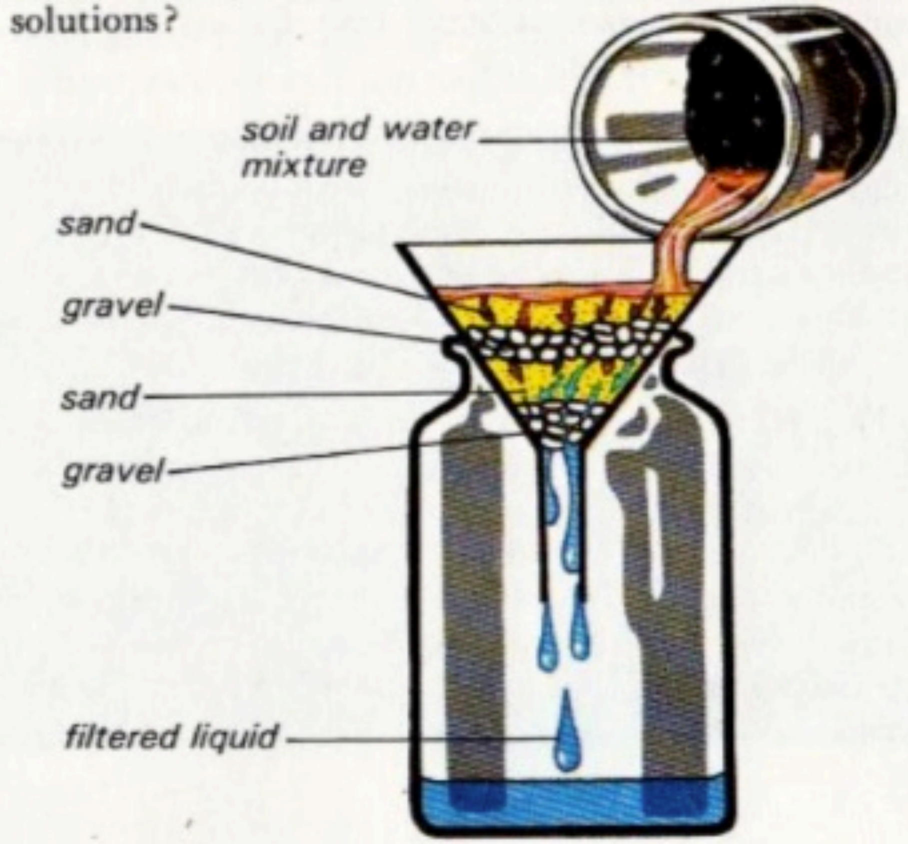
Chemists have to separate fine particles of solids which are floating or mixed in liquids. If the particles are so small that they would slip through a kitchen sieve, chemists use *filter paper* to clean liquids. What happens on a bigger scale? All our domestic water needs purifying so the chemists have devised a way of filtering out the impurities. At the Water Works, water is passed through huge layers of sand and gravel called *filter-beds*. This cleans the water.

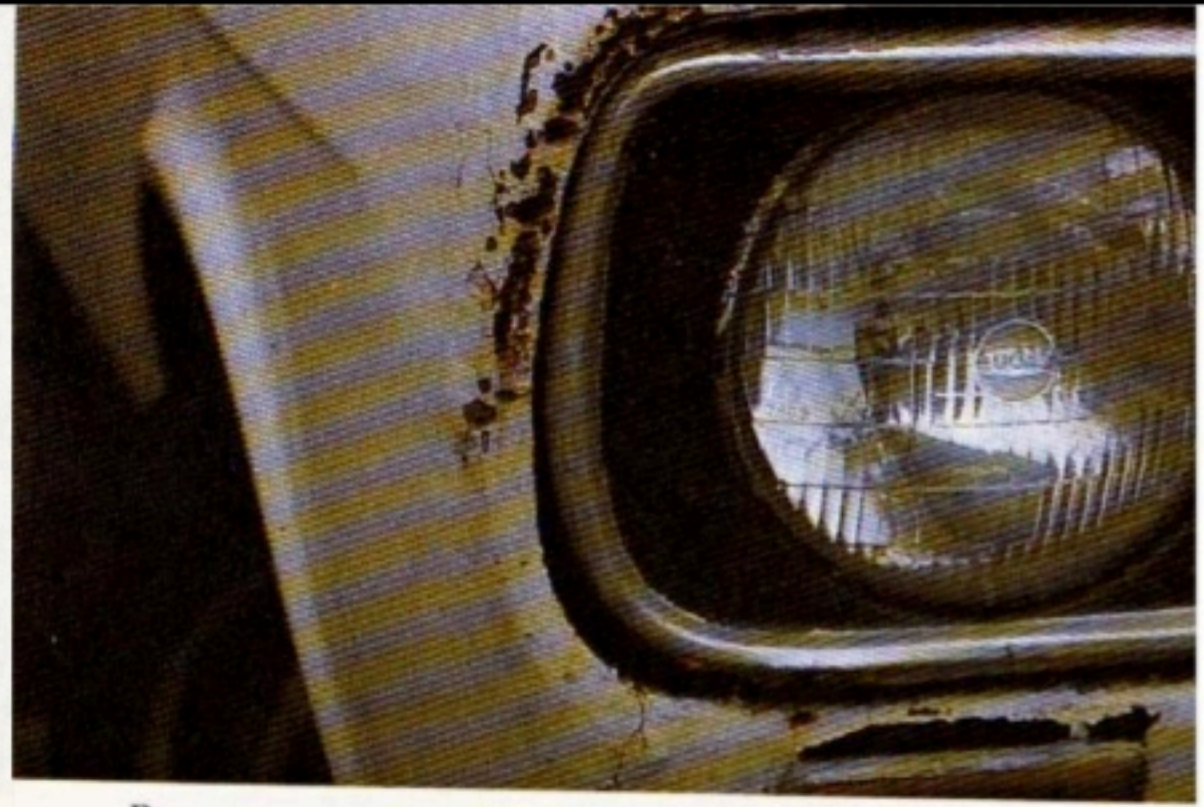
Try it for yourself and see how it works.

(1) Put some sand and gravel in layers in the top of a funnel.

(2) Make a muddy mixture of soil and water and pour this into the top of the funnel and collect the water in a jar. Is the water clear? Does your filtering system work?

(3) What happens if you pour through some cold coffee or tea? Can you use this method for straining solutions?





Rust

Rust is a problem. Iron and steel develop brownish red patches of rust when they are unprotected and exposed to damp air. Some chemical fumes from factory chimneys can also cause metals to rust.

Rust is a chemical change called *oxidation*. It happens when metal and oxygen combine. First a small blob appears on the metal which gets bigger and flakes off, leaving a new surface to be attacked. Iron bridges have been known to weaken and collapse through the effects of rust and we often see patches of rust on old cars.

The metal can be protected against attack from rust by coating it with paint, oil, or some non-rusting metals. The metal, *chromium*, does not rust and car bumpers, headlights, and our bathroom fittings are protected by chromium plating. Tin is another non-rusting metal and is used in the canning industry. Nowadays, plastic is often used instead of metals because this will not be attacked by oxygen and water.

Let's find out how to prevent rust.

Things you need:

jam jars	Vaseline
house paint	9 shiny iron nails
cooking oil	

To discover which conditions are best for rust, make sure you choose different kinds of places to set up your experiments. In the warmest, coldest, lightest and darkest places in your home, put a jar with a shiny nail inside. Check after a few days. Which jar has the rustiest nail?

(1) When you have found the best rust-growing place, get four jars. In the first jar, put a dry shiny nail.

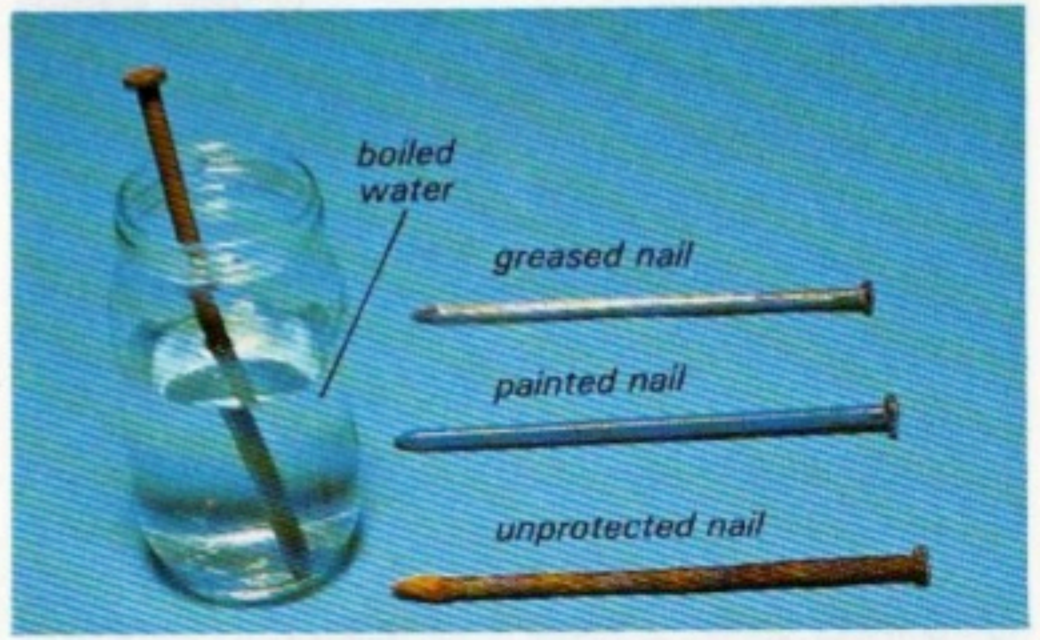
(2) In the second jar, put a nail covered with paint.

(3) In the third jar, put a nail covered in Vaseline grease.

(4) In the last jar, put a nail dipped in oil.

(5) Put all the jars in the best rust growing position and leave them for a few days. What happens?

(6) Now put a nail into a jar of boiled water, with half the nail sticking out of the water. Which half rusts? Why does only half the nail rust?



The chemistry of cooking

When one is cooking, chemistry helps. Without certain ingredients to create a chemical change, many recipes would not work.

If you try to make bread without *yeast*, it wouldn't *rise*. You would produce hard, flat bread. Yeast is a tiny fungus which grows by developing small buds to form new plants. As the yeast grows it gives off carbon dioxide which forms little gas pockets in the dough. To start this process the dough must be worked well with the hands. This is called *kneading* and must be done for at least ten minutes.

Sugar feeds yeast and quickens the growing process. Salt slows down the yeast growth but makes bread taste better. The salt is therefore mixed with the flour so that it does not come into direct contact with the yeast.

A loaf before and after baking which shows the effect of yeast

Let's experiment with yeast and watch how sugar reacts with it.

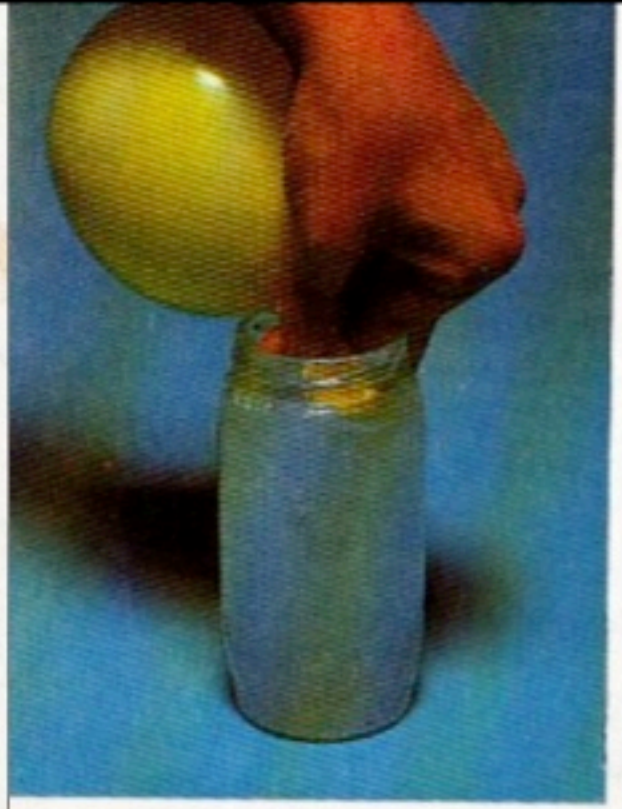
Things you need:

sugar
balloon
jam jar
limewater
dried yeast
bottle
teaspoon

What you do:

(1) Half fill a jam jar with warm tap water and add five teaspoonfuls of sugar.
(2) Stir until the sugar dissolves.
(3) Pour the solution into a clean bottle and wash the empty jar.
(4) Mix one teaspoonful of yeast and two teaspoonfuls of water in the jar and carefully pour this into the bottle.
(5) Fix a balloon tightly to the neck of the bottle, tying it round and round with string so that it can't blow off. Put it in a warm place.

The yeast gives off carbon dioxide gas which inflates the balloon



The carbon dioxide turns the limewater a milky colour

After a while the solution will begin to bubble and slowly the balloon will be blown up by gas made by the yeast acting on the sugar. Carefully pinch the neck so that the gas doesn't escape and remove the balloon. With the neck of the balloon under the surface of a jar of limewater, let the gas escape. What happens? (Don't forget to wash your hands.)

Baking powder acts in the same way as yeast by giving off carbon dioxide when mixed with water and heated. Plain flour, margarine, sugar, eggs and milk combine to make a cake but you must add baking powder if the cake is to be light and fluffy. Self-raising flour already contains baking powder or a similar substance to make cakes rise.

Cream of tartar is sometimes used for making scones because it too helps the mixture to rise. Yeast, baking powder and cream of tartar are all known as *raising agents*. Cream of tartar is a fine white powder obtained from the bottom of wine storage barrels and casks. The powder develops from fermenting grape juice which contains tartaric acid.

When some fruits and vegetables are cut and exposed to the air, they turn a dark, unattractive colour. Bananas, apples and potatoes do this. Chefs use lemon juice to prevent this discolouration. As soon as the food is cut, squeeze the juice over and the citric acid in lemons does the trick.

Another acid used by cooks is vinegar, which is used to preserve food from deterioration. The word vinegar comes from the French, *vin aigre*, meaning sour wine. Food stored in vinegar is *pickled* and onions, cucumbers, cabbage and beetroot are the most common ones. The vinegar stops the food from turning rotten and also gives a very characteristic flavour.

There are two groups of vinegars: malt vinegars which are made from beer, and wine vinegars, made from grape and other fruit juices. Both are produced by the action of bacteria on the wine or beer.

Many years ago, before refrigerators had been invented, it was very difficult to keep meat fresh for more than a day or two. Joints of meat, bacon and fish were salted to preserve them for eating at a later date. The bacteria which turns food bad cannot reproduce in salt and so travellers often took salted meat with them on long journeys.

Housewives also used to smoke their meat and fish in the fireplace, because smoking also preserves food by killing off the bacteria which would affect the food.

Let's experiment with cooking by making some American baking powder biscuits.

Things you need:

225 g plain flour	mixing bowl
110 g margarine	rolling pin
90 ml (3 fl oz) milk	knife
10 g baking powder	board
5 g salt	pastry cutter
	baking sheet
	fork

Turn on the oven at gas mark 7 (electric 220C/425F)

What you do:

(1) Divide each of the ingredients into two equal parts. Use the first group to make the baking powder biscuits as given below.

(2) Put the flour, all 10 g of baking powder and salt into a mixing bowl and mix them together well.

(3) Add the fats in small pieces and rub with your finger tips until the mixture looks like small bread crumbs.

(4) Add some milk until the mixture forms a soft doughball.

soft doughball

(5) Cover a board with flour, and also your hands and the rolling pin.

(6) First knead the dough gently until it is smooth.

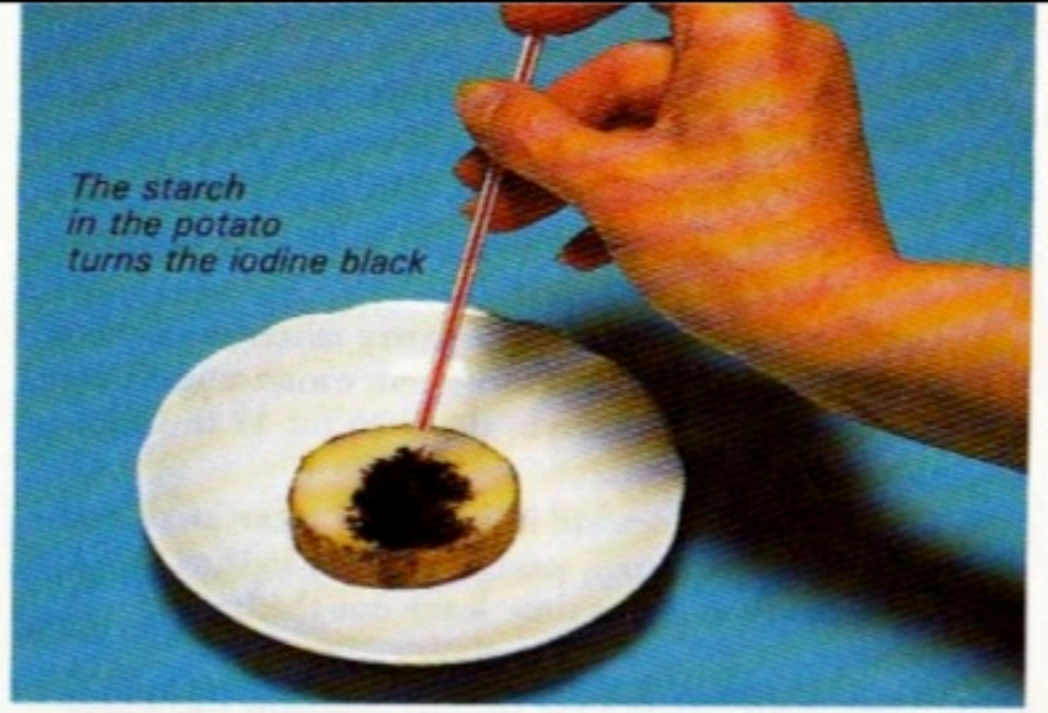
(7) Now use the floured rolling pin to roll the dough until it is 2 cm thick.

(8) Cut out the scones, using a pastry cutter, and prick each one with a fork. Place them on an ungreased baking sheet and bake in the oven for 12 to 15 minutes.

(9) While these scones are in the oven, clear away and make another batch, using the other half of the ingredients, but this time leave out the baking powder.

(10) When both batches are baked, compare them and see what difference the baking powder made to the first group. Which group look like scones: the ones with or without the raising agent?

The Americans call our scones, "biscuits", and our biscuits, "cookies". You have made scones but your second group probably look like English biscuits because they had no raising agent.



The starch test

Many foods that we eat each day contain *starch*, a sugar-like substance that people on diets want to avoid. You can easily test foods to see if they contain starch.

Things you need:

bread	old saucers
carrot	straw dropper
raw meat	tincture of iodine (obtainable from the chemist)
slice of potato	jam jar
apple	plastic spoon
dried white rice	

What you do:

(1) Make a solution of the iodine by adding 5 drops of iodine to the jam jar and pouring in cold water until it is 6 cm deep. Stir well.

(2) Put the potato on a saucer and drip onto it 2 or 3 drops of iodine solution. Watch the potato turn bluey black. Iodine is an indicator for the presence of starch. Now test all the other foods you have collected and see what happens.

Mouldy food

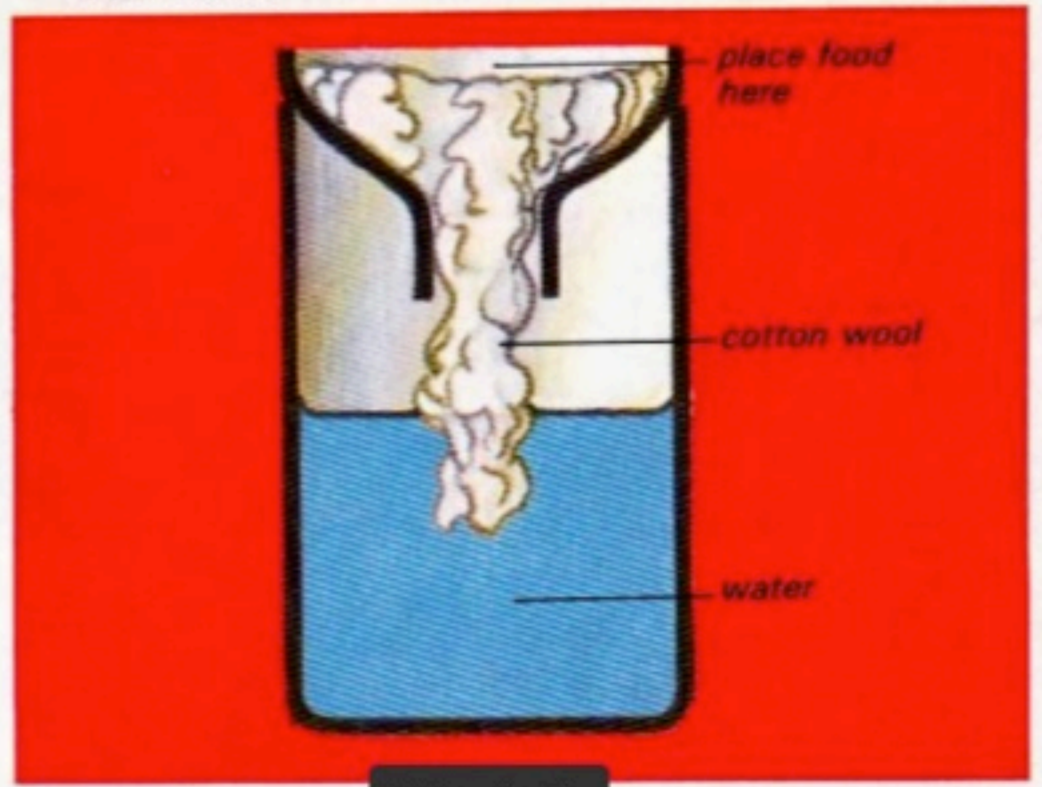
Keeping food fresh is a problem. In damp, moist conditions much of our food goes mouldy if it is not protected. Moulds are tiny plants called fungi, and their minute *spores* (seeds) are in the air we breathe. Moulds are easy to grow. Let's find out how to grow them.

Things you need:

washing-up liquid bottles	cotton wool
polythene bags	elastic bands
a slice of cheese	a slice of apple
orange peel	bread
a piece of old leather	some small stones
a scrap of plastic	

What you do:

(1) First you need to make mould growers from the washing-up liquid bottles. With scissors, carefully cut round the top part of each bottle. Turn the top upside down to form a funnel and place it in the bottom section (see diagram). Fill the bottom part with water.



(2) Put some cotton wool in each funnel and pull it through the spout. Place the funnel back on the base and make sure that the cotton wool touches the water and is soaked.

(3) Put different food in each mould grower, cover it with a polythene bag and place it on a window sill. Check each day to see what is happening and record this in your notebook.

Which foods grow moulds? Are the moulds a different colour? Which food grew mould first? Now put the leather, some stones and the plastic in different containers and see what happens.

Moulds only grow on things that have once lived. Such materials are called *organic*. Things which have never lived are called *inorganic*. A stone, which is inorganic, does not give mould spores anything to feed on.

Did the orange peel grow a blue mould? This is *penicillin*. Penicillin is used as a medicine. Sir Alexander Fleming (1881-1955) discovered this by accident. He left a dish of bacteria uncovered and later found that it had mould on it. The bacteria round the mould had died and from this observation Fleming, in 1928, discovered the drug that has since saved thousands of lives.

Mould on bread

Sterilisation

Louis Pasteur (1822-1895) was a French chemist who was fascinated by moulds. He developed a method, known as *pasteurisation*, to make milk safe to drink by removing harmful bacteria. He did this by heating the liquid and this killed the germs. Hospitals *sterilise* instruments and dressings to prevent infection spreading, by heating them in special containers called *autoclaves*.

A commercial autoclave which sterilises dressings before they leave the factory

Chemistry in the garden

Garden soil is normally fertile enough for growing vegetables and flowers. Vegetables are greedy feeders and take a lot of goodness from the soil as they grow. Each time a gardener uses the soil he or she should put back the goodness for the next crop. This is done by treating the soil or "digging in" with animal manure, man-made fertilisers or organic compost.

Fertilisers provide chemical substances that are necessary for good plant growth. There are four chemical substances which are very important for the garden.

Nitrogen makes plants grow as big as possible. Plants that grow in ground which is short of nitrogen are stunted and often yellow in colour.

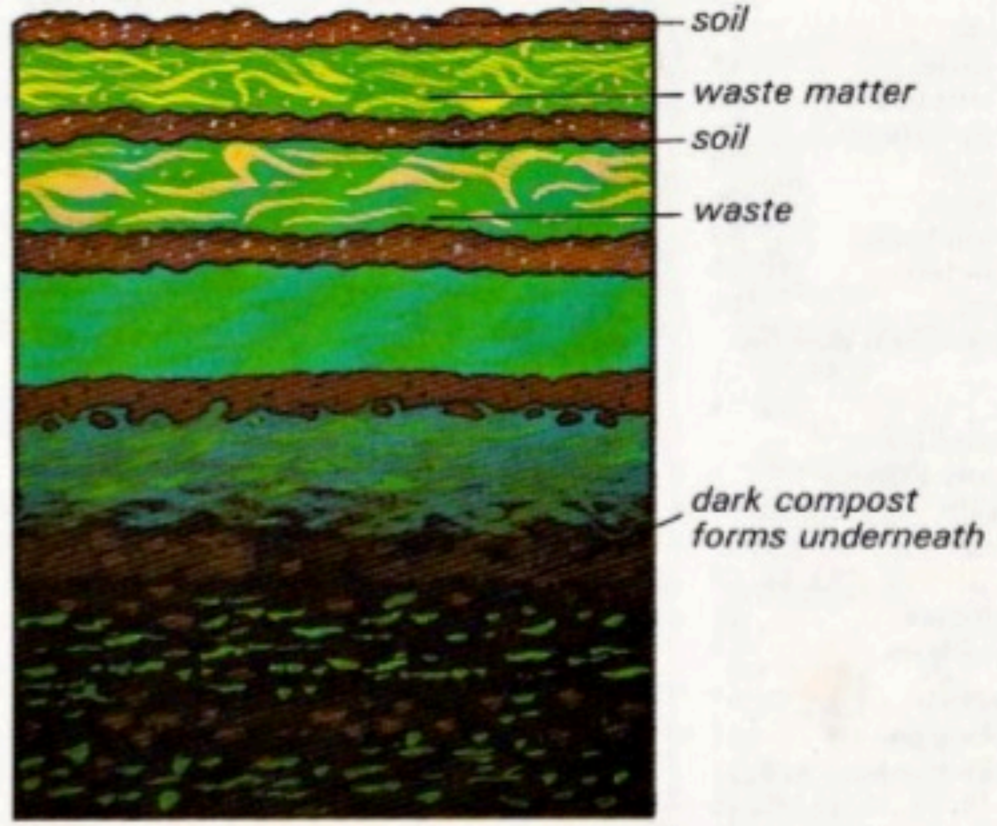
Potash promotes the health and vigour of plants, helps disease resistance, and maintains the colour of their leaves and flowers.

Phosphorus encourages the growth of good fruit and flowers.

Lime maintains the acid/alkali balance in the soil so that plant food, in solution, can be absorbed through the root hairs of the plants. You could test whether soil is acid or alkali, by using the indicator described on page 29. Also, very alkaline soils will fizz when tested with vinegar.

Crop spraying

A compost heap



Chemists have developed many different kinds of fertilisers to help the gardener and the farmer. Next time you visit a garden centre, look at the different chemicals on display.

Many people prefer to use natural plant food made by slowly rotting vegetable waste, table scraps, and grass cuttings in a compost heap. The waste scraps are piled high and sprinkled with soil at intervals. The heap gets warm as it gets bigger, due to the action of the bacteria which causes the materials to rot down to a dark compost. Farmers also spread rotting manure on their fields.

Chemists make liquid fertilisers for houseplants. These are concentrated and need to be diluted with water before use. They contain all the chemicals that plants need and act very quickly. As their effect is not long lasting, liquid fertilisers need to be fed to plants regularly during the growing season.

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